and white, and preferably after black and white copying?		
343. Are appropriate references made to figure, table and equation numbers in the text?	Yes	
344. Are appropriate references made to references in the reference list?	Yes	
345. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Probably not	
Other		
346. Has the report been written by you individually?	Well, most of it	
347. The work has been carried out in collaboration with: Jasmine Sattari Far		-
348. The report has been proofread by:		-
349. I believe that this report as a whole is worth rating (u, 3-5)	3	
350. The following is a reflection on how I believe that the work with this report and related projects relates to set learning goals (relevance of the work, which goals have been met, etc.):		-

WAYDOO 1003

CONFIDENTIAL

WD086543

TB115- Batteries 48 volts



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Course:	Marine design
Project:	
Date:	*2009-02-19.*
Version number:	*0.9*
Supervised by:	
Hours worked:	15 h
Reviewed by:	

Introduction

As the project's wish motor is powered by a 48 volt system, either existing batteries need to be supplemented or new ones procured. This PM is a short description of the results of a small benchmarking study. The majority of the information comes from the internet.

Needs

The Torqeedo motor operates with a voltage of 48 volts and a power output of 4 kW. Unfortunately, their catalog does not give an exact information on what consumption the motor has. Probably it can be assumed that it should not exceed the power / voltage which is about 83 Ah. However, they state that the engine should be able to run for 2 hours at full speed with a traditional lead acid 200 Ah battery pack as it drives a 30 foot boat [1]. This indicates that a maximum consumption of 83 Ah is probably a good estimate. Torqeedo seems to expect that you should have about 25% extra capacity because the theoretical operating time is never the same as the practical one as a battery is heavily loaded. If we wanted to drive 20 minutes at full speed, we consume about 27 Ah. With 25% extra capacity, we should thus have a battery of at least 34 Ah.

Option

For our part, there is really only one type of battery if we are to use 48 volts, namely batteries of the type Lithium Iron Polymer (LiFePO4). A conventional solution with lead acid batteries would weigh upwards of 100 kg and take up far too much space. I do not intend to go into the technology behind how the LiFePO4 batteries work.
The benefits are:

- Very safe (no risk of explosion)
- Extremely light in relation to its capacity
- Can handle high current
- Resistant to deep discharge
- Can handle many charge cycles
- Easy to build in as they are delivered in small packages that can be connected in series or in parallel
- Environmentally friendly

The disadvantages are:

- The price
- Difficult to obtain
- The quality can be so so

Below is a presentation of the options I have found.

Option Celltech

Celltech was the supplier of the batteries for last year's project and we also have access to these this year. Unfortunately, they are 24 volts and to be able to use these, we must have another identical collection of batteries and connect them in series. The weight would then be a total of about 40 kg and the capacity 54 Ah. These batteries are further investigated by Fredrik Bender in a battery analysis [2]. The batteries sold by Celltech come from a reputable Taiwanese manufacturer called Phet. They also make battery packs with smaller capacity that are lighter. For example, one could imagine 16 battery packs of their type no 3. It would give 42 Ah and a total weight of about 32 kg. Fredrik Bender has established a contact with Joacim Asp who is the CEO of Celltech. I myself

have not contacted him about prices or opportunities to either get another set of the batteries we already have or get a brand new set. In Figure 1, there is a clip from Phet's specification [2].



Item No. / Cell Type	14	13	12	11	10	9	8	7	6	5	4	3	2	1
SP1100-88(A)	3.2V 112Ah	3.2V 88Ah	3.2V 79Ah	3.2V 66Ah	3.2V 62Ah	3.2V 57Ah	3.2V 53Ah	3.2V 48Ah	3.2V 44Ah	3.2V 40Ah	3.2V 35Ah	3.2V 31Ah	3.2V 26Ah	3.2V 22Ah
PE1150	3.2V 138Ah	3.2V 92Ah	3.2V 83Ah	3.2V 69Ah	3.2V 65Ah	3.2V 60Ah	3.2V 55Ah	3.2V 51Ah	3.2V 46Ah	3.2V 42Ah	3.2V 37Ah	3.2V 32Ah	3.2V 28Ah	3.2V 23Ah
GE1200	3.2V 144Ah	3.2V 96Ah	3.2V 87Ah	3.2V 72Ah	3.2V 67Ah	3.2V 63Ah	3.2V 58Ah	3.2V 53Ah	3.2V 48Ah	3.2V 44Ah	3.2V 39Ah	3.2V 34Ah	3.2V 29Ah	3.2V 24Ah
EP1500-07B	3.2V 180 Ah	3.2V 120Ah	3.2V 108Ah	3.2V 90Ah	3.2V 84Ah	3.2V 78Ah	3.2V 72Ah	3.2V 66Ah	3.2V 60Ah	3.2V 54Ah	3.2V 48Ah	3.2V 42Ah	3.2V 36Ah	3.2V 30Ah
Total Cells	126	80	72	60	56	52	48	44	40	36	32	28	24	20
WEIGHT (APPROX.)	7.2KG	4.85KG	4.5KG	3.84KG	3.72KG	3.46KG	3.16KG	2.88KG	2.66KG	2.4KG	2.18KG	1.94KG	1.68KG	1.48KG
SIZE (APPROX.) H×W×T (mm)	410×150×67	410×150×67	381×150×67	328×150×67	310×150×67	282×150×67	274×150×67	254×150×67	236×150×67	217×150×67	199×150×67	180×150×67	163×150×67	144×150×67

※PHET® reserves all rights to change the wording and specification without prior notice.

Figure 1, Specification of Phet's various battery packs.

Option Ebay

There are a number of smaller companies that sell LiFePO4 type battery packs on Ebay [3]. These are then sold designed for, for example, electric motorcycles or the like. The figures given show that they would not withstand such high discharge currents as Torqeedon has. However, they write that special solutions are possible on request. The weight of a 40 Ah battery is around 20 Kg and they are 35x28x14 cm in size. The price varies from SEK 7-12,000. The batteries that are available are not enough, but then we have to send a request for better things, but this option still feels a little too risky. If you read reviews from buyers, it can be a winning lottery as well as a real raffle. Although they provide a guarantee, sending a battery back to China is not exactly free.
In addition, they are sold in finished modules similar to ordinary car batteries and do not have the same adaptability. Figure 2 shows a picture of a typical appearance of such a battery.



Figure 2, Battery from China for sale on Ebay

Option Tenergy

Tenergy is an American manufacturer of LiFePO4 batteries. They sell a battery similar to the Ebay variant, which seems much more solidly made. They are sold in packages of 20 Ah each, which weigh just over 10 kg and measure 281mm x 155mm x 196mm [4]. Two batteries connected in parallel would thus provide sufficient capacity. Unfortunately, the maximum discharge capacity is at the limit of what the motor requires and the only dealer I have found unfortunately only sells to the USA and Canada. Figure 3 shows a picture of the battery.

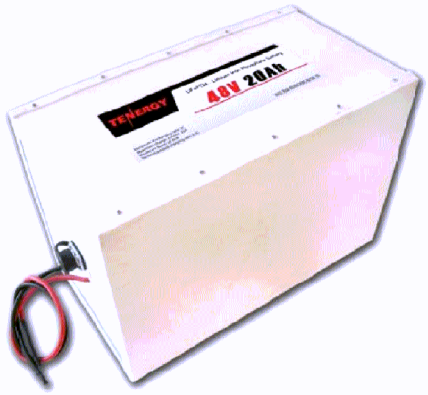


Figure 3, Tenergy's battery

Option Thunder sky

Thunder Sky is a Chinese manufacturer that also sells batteries in smaller series directly from the factory. The company also makes ready-made electric vehicles with everything from small electric motorcycles to large electric buses in its product portfolio. The batteries are popular among electric vehicle enthusiasts because they have good quality, good performance and yet a fairly low price. In the investigation of option motor solutions, I came in contact with Oscar Theen at OZ-marin, which sells electric motor solutions for boats. He told me about a guy named Håkan Borgh. Håkan is the founder of the company Roiro, which manufactures an electrically powered small boat, Whisper 55. Together with one of the country's leading experts in boat electricity, Anders Jangö has experimented with batteries from Thunder Sky. They have had problems with the charging of the batteries and have therefore together developed their own patented charger. They currently have two boats to be delivered with LiFePO4 batteries from Thunder sky. According to Håkan, you get up to half the price of the batteries if you order more than 100 and he was very happy with my contact because our need would probably make them come over the limit for a discount. The type we would use weighs 1.6 kg and measures 116 × 190 × 46 mm. They provide about 3.0 volts at load and we would thus need 17 batteries in series. The capacity is as much as 50 Ah and the total weight lands at 27 kg [5], which compared to the Celltech option provides significantly more energy per kg of battery. Håkan did not have current prices, but the latest information he received was that with a purchase of 100 batteries, each battery would require a price of 1.25 dollars per Ah and battery, which means that each battery costs 62.5 dollars. He also recommended buying a few extra so calculated on 20 batteries, the total cost would be 1250 dollars, which with a dollar price of 9 SEK would mean that the batteries would cost us 11250 SEK. If we buy it ourselves, it will be about twice as expensive. In addition, it is not entirely easy to shop from the Chinese as they have a complicated banking system and must have paid in advance. Buying the batteries through him would thus be a huge advantage. We would probably also be able to agree that he should buy back the batteries after we used them at a good price, which would make us get away even cheaper. I will

meet Håkan and his partner Anders at the Boat Show. They plan to place their order in early March. Normally it takes about 3 weeks until the batteries are in Sweden. Figure 4 shows a picture of a battery.

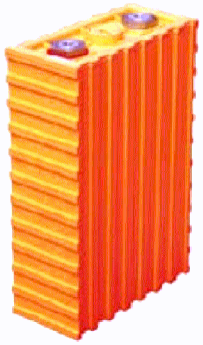


Figure 4. The TS-LCP50AHA battery from Thunder sky

Conclusion / recommendation

As the reader has probably already noticed, it is quite clear which option I advocate. The battery from Thunder Sky has superior price performance in relation to weight. In addition, we have a good contact to buy via who has already tested these batteries with very good results under similar conditions that we will use them in. My recommendation is that if we get the Torqeedo 4.0 engine, we buy 20 batteries if we still have the old Torqeedo 2.0, my recommendation is in any case that we buy 10 batteries of this type as we would then reduce the weight by 7 kg from current batteries. The second option is to make new contact with Celltech and find out what they could deliver and what it would cost. But we would in any case get batteries with poorer capacity that weigh more and take up more space if we chose theirs.

References

1. Torqeedos katalog nedladdad från internet, http://www.torqeedo.com/uploads/media/Torqeedo_Cat_2009_metric_measures_01.pdf tillgänglig 2009-02-19
2. Rapporten A106 – Batterier av Fredrik Bender, KTH Marina System , opublicerad
3. Internet, ebays internationella sajt, ,http://www.ebay.co.uk/?_trksid=m38 sökord LiFePO4 48* 40*
4. Återförsäljaren av Tenergy batteirer allbattery, http://www.all-battery.com/48V20Ahlifepo4lithiumironphosphaterechargeablebattery-1-1-1.aspx , available 2009-02-19
5. Batterspecifikation från tillverkaren Thunder Skys hemsida, http://www.thunder-sky.com/pdf/TS-LCP50.pdf , available 2009-02-19

Manufacturing report handle



ERIK JERILGÅRD
FREDRIK BENDER
MARKUS NORBERG

Course:	Marine design
Project:	Evolo
Date:	*26/03-2009*
Version number:	*2.0*
Hours worked:	Too many
Reviewed by:	Mirjam Fürth

Handle

The handle was made of aluminum pipes with an outer diameter of 30mm. This was bent using a hydraulic press to the shape specified in the report for Evolo's handle TB101.
The weight of the handle is 1.25kg.

Mounting points for handles

The mountings to the handles are made of steel pipes with an inner diameter of 31 mm welded to thin metal blades. The two aft are of the size 100 * 200mm and the front 100 * 100mm. The weight of these is 2.2kg. Screw holes in these have not been made as this is safer to do as it is determined where and how they should be attached to the floating body. The plates can then be attached to Evolo's floating body and then the handle can be attached to these by sliding it into the mountings. This also means that the handle can be disassembled relatively easily. These mountings shall be spaced apart as specified in Figure 1.

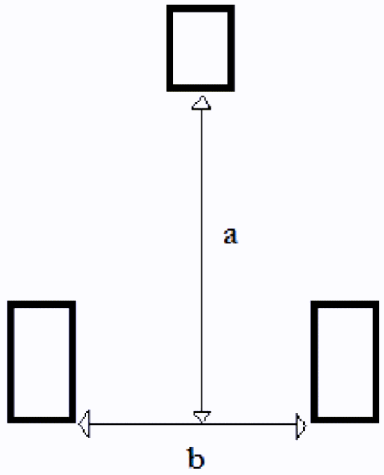


Figure 1. The mutual distance of the mountings

Distance	mm
a	470
b	658

Final assembly

When final mounting on Evolo, the plates will need to be provided with boreholes to be able to be attached to the insert. Once it has been determined where these are located, the size of the mounting plates can also be reduced to save weight. The pipes on the mounting plates may also be shortened at this stage, as may the handle itself when it is mounted. The fact that these are currently oversized is to allow fitting even if the manufacture of the floating body goes wrong and that the insert does not end up in the intended position. Final assembly takes place when the manufacture of the floating body has been completed and the location of the laminated aluminum mounting plates has been determined (*see TB120 - Building floating body for placement of mounting plates*). When this is done, the handles with the mountings must be corrected so that they can be attached to the floating body.

Appendix 41 TB118 Manufacturing report propeller

Propeller manufacturing



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Course:	Marine design
Project:	Evolo
Date:	*27/3-2009*
Version number:	*1.0*
Hours worked:	
Reviewed by:	Nils Wolter

Introduction

The theory behind the propeller is described with its assumptions and limitations in the report ”A101 Propellerval” [1]. The optimization was then done for the engine we had, ie Torqeedo 2.0. A little later during the project, we learned that we could both buy the stronger Torqeedo 4.0 and that this could be delivered with a significantly higher speed (1500 rpm instead of 920 rpm that Torqeedo 2.0 has). With the same program that was written for the propeller to 2.0, a new propeller was developed. The new speed enabled dimensions of the propeller that are much smoother than before and also opened up the possibility of shorter chord on the propeller blades so that the efficiency could be increased.

Purpose

The purpose of the construction of the propeller was changed when we found out that we would get the stronger Torqeedo 4.0 engine. From being crucial to getting the Evolo up to a speed higher than 5 knots, propeller manufacturing is just a project to be learn. The variable motor also comes with a high-speed propeller which, according to the manufacturer, should be able to get an inflatable boat up to 13 knots. With the knowledge of this, the propeller is built to be able to be compared with Torqeedo's own. As the performance of the propeller does not jeopardize the project, a two-bladed model has also been chosen to evaluate the importance of several blades. Thus, the purpose of propeller construction can be summarized in the following points

1. Opportunity to compare propeller theory with reality.
2. Opportunity to get a better perspective on what different angles dimensions of the propeller actually correspond to in reality.
3. A chance to see if it is possible to "tailor" a propeller for a specific purpose (ie given speed for given resistance).
4. Opportunity to find out the importance of several blades.

Performance

The propeller was manufactured based on the production plan ”TB113 – Propellertillverkning” [2]. First, three forms were made for the then current speed of 1250 rpm. According to the optimization program, such a propeller with three blades would have the dimensions:

Chord	12 cm
Diameter	35 cm
Geometric pitch	0.45

The forms were made by dividing the length of the blade into 8 segments. The geometric angle was then calculated for each segment, whereupon the different segments were joined and filled to create a continuous surface, see Figure 1.

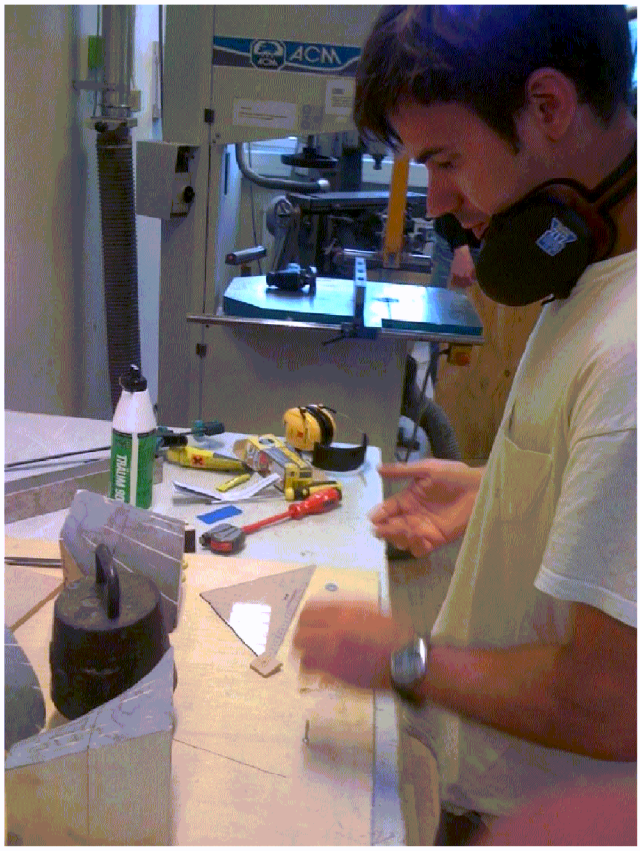


Figure 1 *Propellerform version 1*

The hub was made of aluminum and turned in the same form as the hub of the existing propeller. The set of forms and hubs is shown in Figure 2.



Figure 2 Propeller form version 2

With the knowledge of the new speed, the appearance changed and the now two-bladed propeller got the dimensions:

Chord (max):	5 cm
Diameter:	34 cm
Geometric pitch:	0.33

With lessons from the first propeller forms, two new forms were made, but this time in core material in high density. The angles were again measured out and sand directly into the form. The curvature along the chord was also sanded out, whereupon the forms were filled and "top coated". The set was fixed in a wooden board, after which carbon fiber fabric was soaked in vinyl ester according to [+ -45 0/90+ -45] and placed on the waxed form. The whole package was vacuum packed and allowed to harden for 20 hours. The blades were then removed from the forms and sanded. The forms were then returned and vinyl esters mixed with glass microbubbles were used to attach the blades to the hub. However, this did not turn out to be good enough but pure vinyl ester and a finer carbon fiber fabric was used to fix the blades, see figure 3.



Figure 3 *Propeller blades fixed with carbon fiber fabric*

The fibers were then sanded down so that the surface became smooth. Once these were fixed to the hub, additional fibrous fabric was laid over the blades. These now in the direction 0/90 to increase the strength in the radial direction. The fibrous fabric was thus allowed to run from one tip to another via the hub so that continuity of fiber is obtained. When sufficient strength was obtained, the surface was sanded down and painted with vinyl ester. The surface was sanded and painted repeatedly until the surface became completely smooth. Then the shape was sawn out and the edges were sanded down to reduce the risk of cavitation. The surface was then treated with vinyl ester repeatedly. Finally, propellers were balanced using a shaft, see Figure 4.

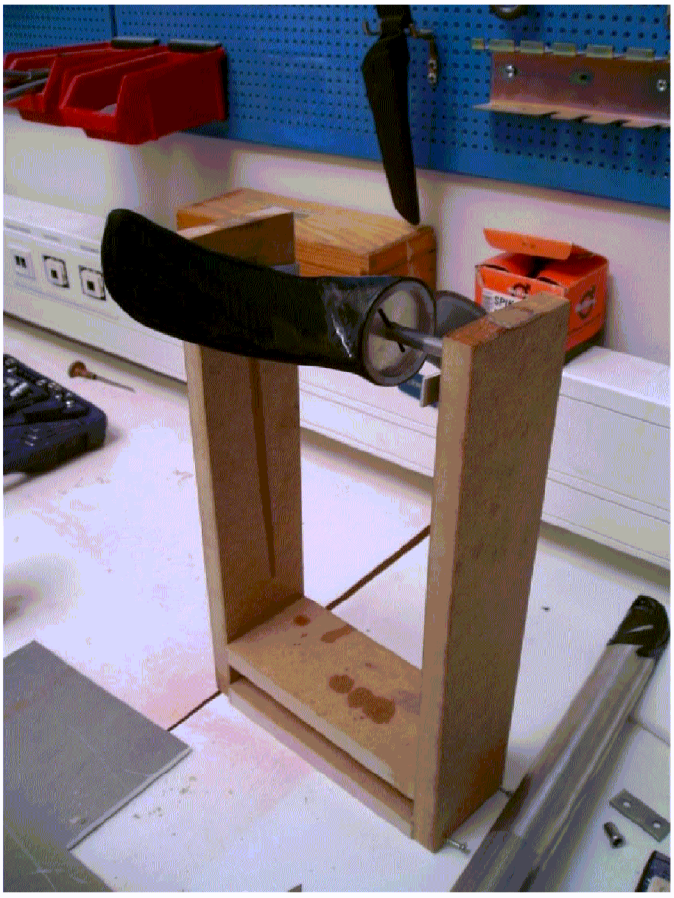


Figure 4 *Balancing device for the propeller.*

When the propeller was balanced, the surface was painted with spray paint, see figure 5 below.



Figure 5 *Propeller with sawn-out shape.*

Conclusion

The conclusion from the construction is the design of the propeller is not so complicated once you have twisted and turned all the geometries enough. However, it was completely impossible to make a picture of what the propeller would look like just from matlab data. However, the biggest lessons will be learned after the propeller has been tested on the Evolo.

References

45. ”TB113 – Propellertillverkning”, www.bilda.kth.se/Evolo
46. ”A101 Propellerval” , www.bilda.kth.se/Evolo

Appendix 42 TB119 Dimensions on the hydrofoil

TB119 - Hydrofoil dimension

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Course:	Marine design / Lightweight design
Project:	Hydrofoil dimension
Date:	*18/3-2009*
Version number:	*1.0*
Supervised by:	-
Hours worked:	12 h
Reviewed by:	Fredrik Bender

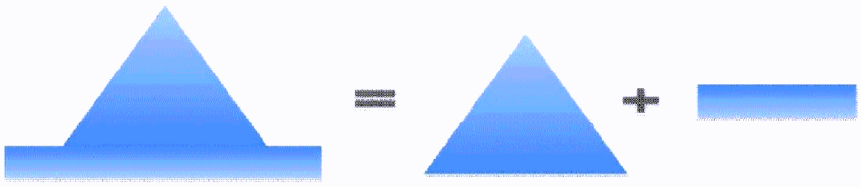
Introduction - problem

In order to enable the manufacture of the hydrofoil configuration and at the same time enable the decision-making to be traceable, a review of previous materials and a brief analysis have been carried out in this area. The purpose has been to track previous decisions made, analyze the most successful hydrofoil configuration and determine current dimensions.

Analysis

A review of previous documentation made of the current hydrofoil configuration has shown that there is no documentation other than certain angles of attack from experiment 4. With this as a basis, the configuration used has been measured and analyzed based on the method reported in *Bärplansberäkningar, 2008, Markus Norberg [1].*

Furthermore, assumptions have also been made so that the new wing, which includes the installation of the motor, is analyzed as a combination of a delta wing and a straight wing according to Figure 1. The effective lifting power is assumed to be 70 percent of that of the model due to the built-in



motor.

Figure 1. Geometric assumption for analysis of front hydrofoil.

Delta wing

The dimensions of the delta wing that have been analyzed are reported below in Table 1.

Table 1. Dimensions for calculated delta wing.

Maximum chord	700 mm
Maximum width	800 mm

Straight wing

The dimensions of the added straight wing that were analyzed are reported below in Table 2.

Table 2. Dimensions for calculated straight wing.

Chord	110 mm
Width	2 x 150 mm

Aft Wing

The dimensions of the aft delta wing analyzed are shown below in Table 3.

Table 3. *Dimensions for calculated delta wing.*

Maximum chord	300 mm
Maximum width	400 mm

For illustrations of the hydrofoil, see Appendix 1.

Results

The analysis of lifting force and resistance for the different wings gave the following results. The intended design load according to *Bärplansberäkningar, 2008, Markus Norberg [1]*, was 1700 Newton which has been marked in relevant figures. Figure 2 shows the lifting force for the delta wing, figure 3 shows the lifting force contribution from the added straight wing, figure 4 the total lifting force of these two. Figure 5 illustrates total resistance from the overall wing configuration including the aft by an angle of six degrees.

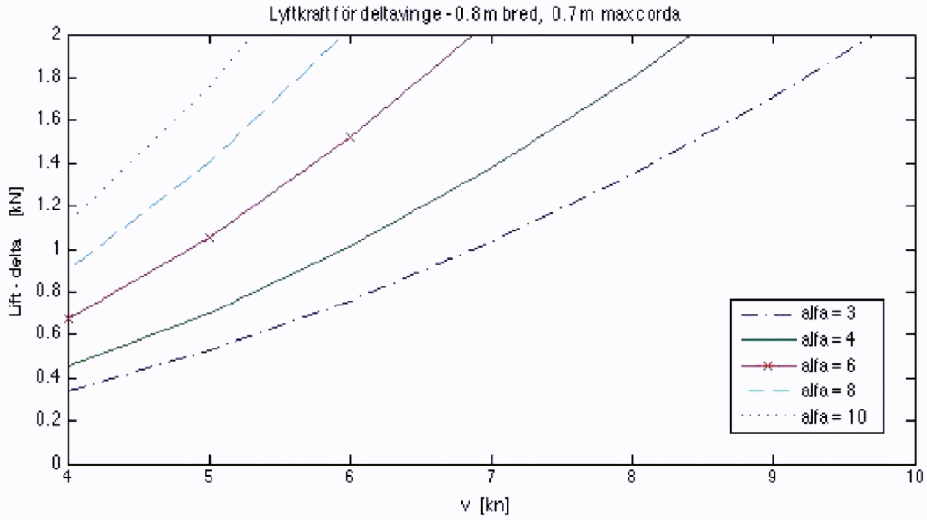


Figure 2*. The lifting force of the delta wing.*

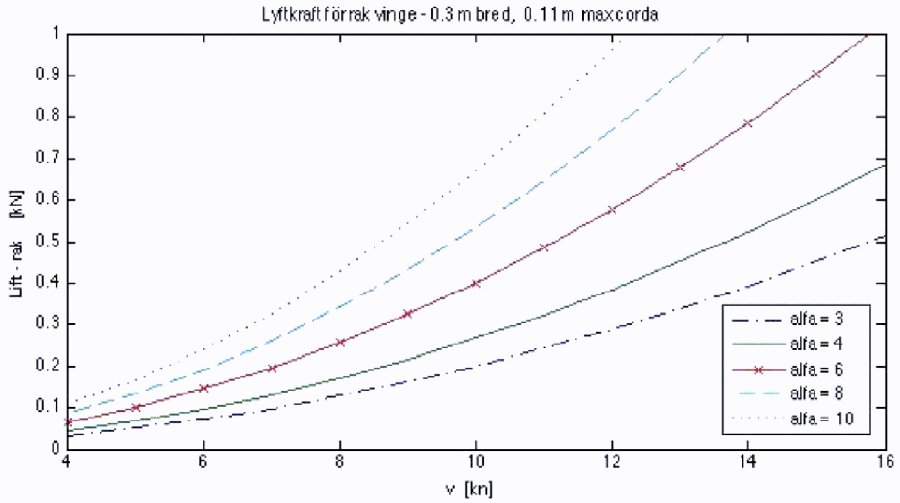


Figure 3. *The lifting force of the straight wing.*

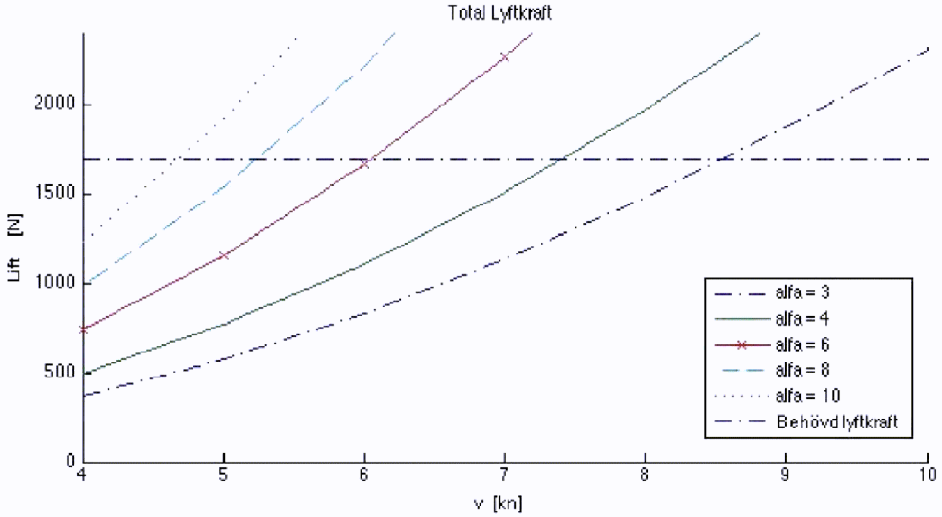


Figure 4. *The total Lifting force from the wing configuration.*

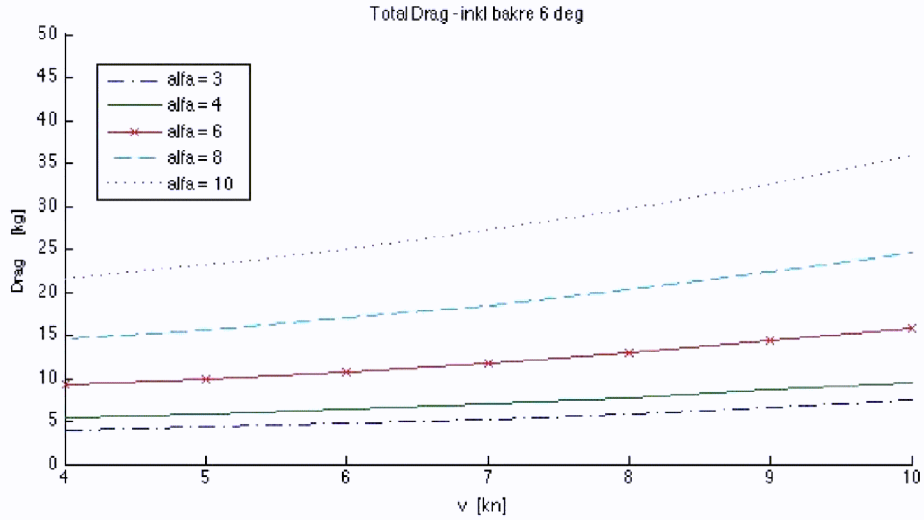


Figure 5. *The total resistance from the wing configuration, including the aft wing.*

Conclusion

The results show that the dimensions presented in Tables one and two are assumed to be sufficient for a front hydrofoil. The required lifting force is achieved within reasonable speeds but does not agree too well with the results of the experiments. On the other hand, it should be added that this analysis should be reasonable to compare with the reality that the angles are far from constant during an experiment. They change all the time as the driver angles the craft itself. It is more or less impossible to compare these results with reality. In order to take into account margins of error and thus implement a safety factor, the dimensions from the hydrofoil used in the experiments have had to grow slightly in the dimensions. In this way, it is assumed that the loss of area as a result of attachment and mounting of the motor is compensated for.

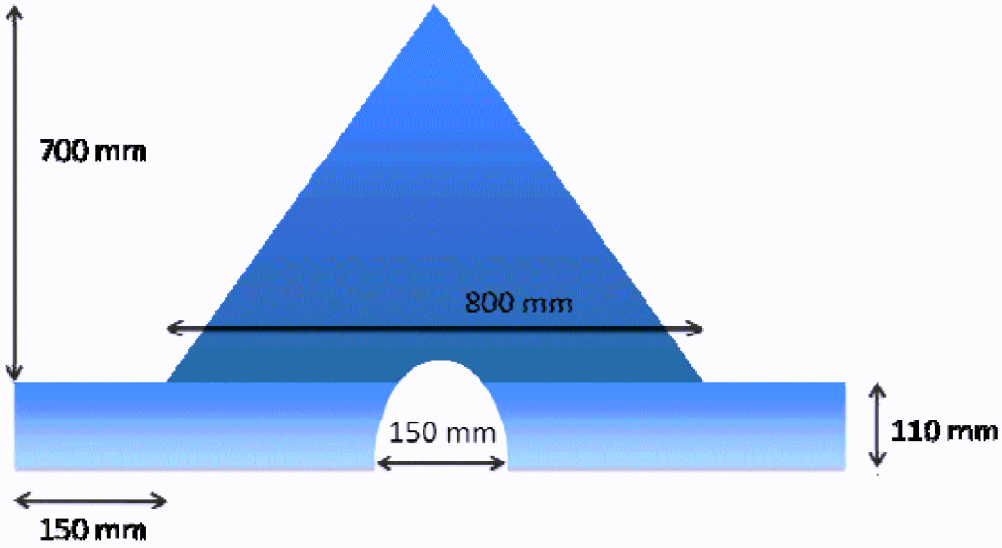
The results verify the dimensions that have worked in reality. The best argument for this is the fact that the wing analyzed has performed very satisfactorily during the experiments. The question remains, however, about how effective the support plan really is in terms of attachments and more.

References

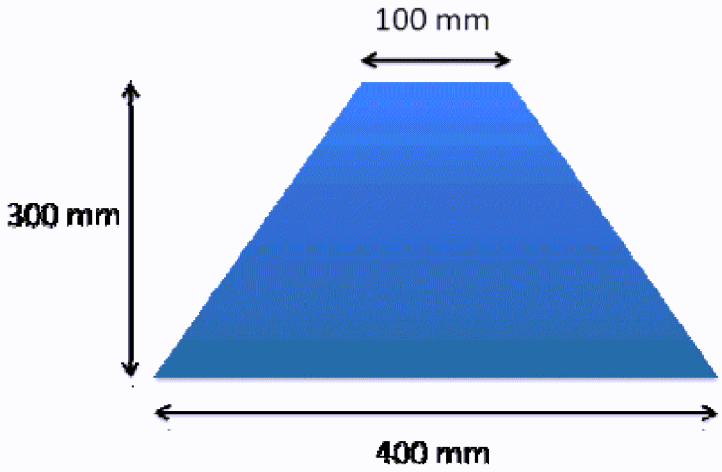
1. A1 - *Bärplansberäkningar, 2008, Markus Norberg.*

Appendix 1 - hydrofoil illustrations

Front hydrofoil



Aft hydrofoil



Appendix 2 - Checklist for Quality Assurance

The purpose of the list is to function as a structuring support for planning, writing and proofreading reports and as support for self-reflection. The list should be used for feedback from proofreaders. Evaluate each point with yes / no and sometimes with a grade of u, 3,4,5. *Note that the completed checklist must be attached to each report!*

General impression	Author Yes/No	Reviewer Yes/No
351. Are all elements of the problem addressed?	Yes	
352. Have the purpose and conditions been reported?	Yes	
353. Have relevant conclusions for the benefit of the project been drawn, reported and related to the objective?	Yes	
354. Is the purpose achieved?	Yes	
355. Is the report readable without access to task formulation, project instructions, etc. that you have received from teachers and supervisors?	Maybe	
Technical content		
356. Have simplifications and assumptions been clearly stated and justified?	Yes	
357. Has the choice of solution methods been clearly reported and justified?	Yes	
358. Are calculations controlled and reasonably assessed?	Yes	
359. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	Yes	
360. Are equations written as part of the running text, presented in separate lines and numbered?	-	
361. Can the technical reasoning be followed?	Yes	
362. Is there a difference between facts, statements and the author's opinion?	Yes	
363. Is there a realistic verification plan for the work in the report?	-	
364. Is there an acceptable follow-up of the verification plan?	-	
Presentation		
365. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	Yes	
366. Is the report provided with: appropriate title, date, author name, e-mail, possible supervisor, summary/abstract, table of contents, reference list and page numbering	Yes	
367. Is the report written in third person passive form? Are experiments described in imperfect, e.g."Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?	Yes	
368. Are figures and tables clear and informative, provided with figure / table text and clear numbering? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black and white copying?	Yes	
369. Are appropriate references made to figure, table and equation numbers	Yes	

in the text?		
370. Are appropriate references made to references in the reference list?	Yes	
371. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Yes	
Other		
372. Has the report been written by you individually?	Yes	
373. The work has been carried out in collaboration with: _____	-	-
374. The report has been proofread by: Fredrik Bender		-

Appendix 43 TB120 Floating body production plan

Petter D

Procedure

As it looks now, the core of the floating body is completely glued in the pool's workshop. Here's a little manufacturing list in bullet form will be listed to clearly explain what to do. It is estimated that two people will be able to stand at Evolo at the same time and sand. But as it will be dusty and difficult, perhaps a group of three people is optimal as this means that rotation can be performed continuously during the work.

1. Inspect the gluing and determine if it is of sufficiently good quality for the work with the floating body to be able to continue.
2. Take a pencil and mark the edge between two frames (transverse or longitudinal).
3. Start sanding. Make sure that you sand down only the highest side of a joint. Look at a CAD drawing so the shape is as good as possible. So rotate the CAD. And it is now that your / your quirky lines come into the picture. Then the line between the frame will end up on the lowest side in the transition between two frames. So after a perfect sanding, all lines should still be visible.
4. Sand.
5. Sand.
6. Sand.

Methods

It is unclear which tools are best for carrying out the work. But try everything. Electric planer, belt sander, etc. It can be an idea to attach longer pieces of sandpaper to approximately equally long planks as this will form excellent tools for making double-curved surfaces. These allow long strokes to be taken, which is good.
If there are any questions about this manufacturing plan, call +46 73 649 05 67.

Appendix 44 TB121 Throttle and cabling

TP121 - Throttle system



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Project:	Evolo
Date:	*07/04-2009*
Version number:	*0.5*
Supervised by:	
Hours worked:	1 hour
Reviewed by:	

Introduction

A production plan must be implemented to facilitate the production of cabling and throttle controls for Evolo. The report on which this plan is partly based is M110 - Mounting Strut/Hydrofoil. Prerequisites are that:

- the speed must be adjustable by the driver in such a way that it does not impede the driver's ability to stay on the Evolo.
- The Torqeedo Cruise 4.0 shall not be modified in such a way that it cannot be assembled to its original condition.

Preliminary study - 4/7-09

Preliminary plan is for the cables to be routed through the strut to the top of the floating body to the existing throttle provided for the Torqeedo Cruise R (see Figure 1) [2].



Figure 35. Throttle for Cruise R.

Preliminarily, this throttle control should be placed inside the waterproof battery container that encloses the top of the mounting of the strut. This means that the throttle control will always be dry and is currently the logical choice.

Mechanical throttle control from this point is preferred to enable the Cruise R to be restored to its original condition and not to complicate the manufacture of the throttle control. In order to regulate the throttle, pulling and releasing a steel wire must cause the speed to increase or decrease, respectively. This is done in such a way that the steel wire is rolled up on a pulley that changes from the wire being extended and shortened to the shaft rotation required to regulate the throttle. In order for a slack wire to mean that the speed is reduced, a torsion spring must be used to return the throttle to its initial position.

This steel wire should then be pulled through a flexible plastic tube to the front of the box. (Cable tubes that are available at the nearest hardware store are preferred.) This is the critical point of the cable routing due to the fact that the battery container must be waterproof and the cable must be pulled in such a way that they do not destroy it. To perform a waterproof bushing, cable glands used on boats must be used and this must be further sealed with wet room silicone.

This tube is then pulled into the handle and consequently this bushing should also be sealed with the same principle as with the battery box. The recommendation is that the throttle regulation takes place with a thumb gas that can be manufactured by a brake handle that is used on bicycles.

It means that this plan generates for other manufacturing groups is that installation of the throttle control must be made possible. The recommendation is that this is attached to the floating body with blind rivets.

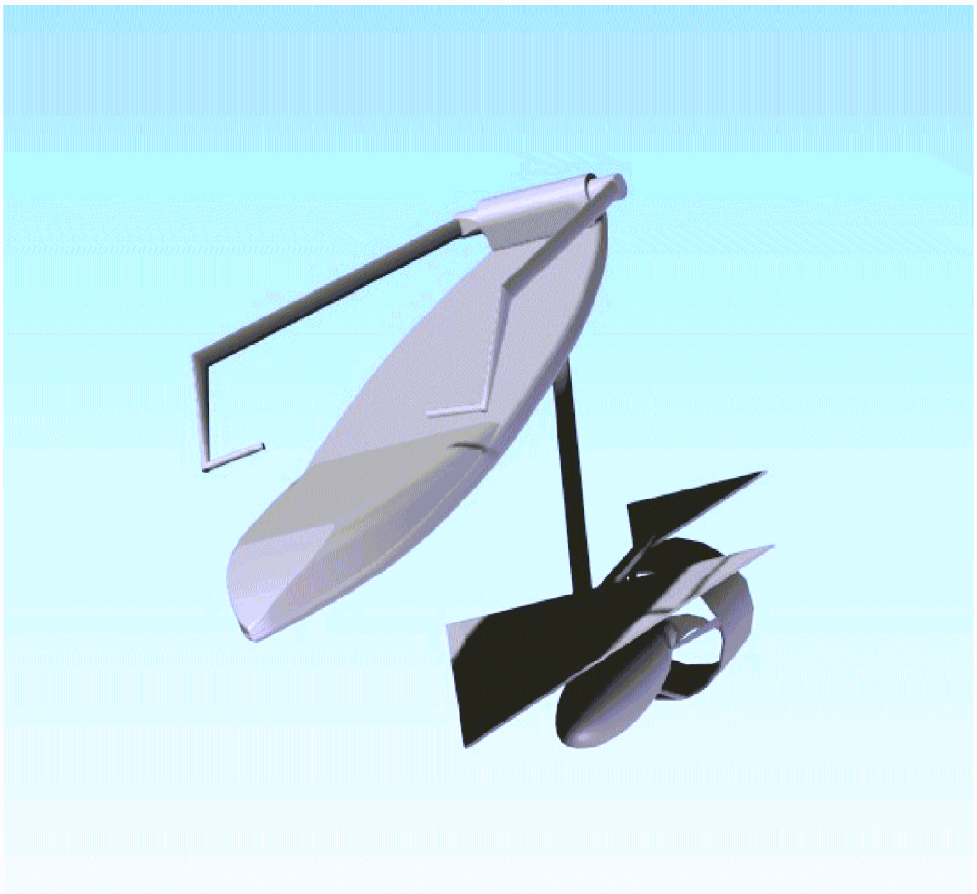
The preliminary study has been carried out due to the fact that a preliminary manufacturing plan must be implemented in order not to put obstacles for other manufacturing and that the manufacturing process stops. The reason why a final manufacturing plan cannot be implemented is because there is not enough information about Torqeedo Cruise R.

Production plan

References

47. Wolter, N & Sattari Far, J: *M110 – Infästning Stötta/Bärplan.* Marina System, KTH, Stockholm, 2009
48. Torqeedo, website; ,www.torqeedo.com product information

Conceptual Design
Evolo



Written by:

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Course: Marine design / Lightweight design

Project:	Evolo
Date:	*22-10-2008.*
Version:	*2*

Introduction

The purpose of this report is to provide an insight into the work of developing Evolo. The project group's goals and vision of what the end product should look like are reported and evidence for this is reported to the extent that it has been investigated.

For two weeks before the start of the project, a concept study was carried out where possible design concepts were investigated. A concept design was selected taking into account the most important attributes that attract customers of water sports and the requirements specification of the projects. The components and form of the selected concept are presented in more details in this report.

Evolo

Evolo is a Latin name meaning fly away, escape or rush. Evolo is an electrically powered composite craft that lifts on a hydrofoil at a speed of about 6 knots.

The most important attributes that Evolo should express are [1]:

- Playfulness
- Speed
- Challenge for the user (with endless possibilities to develop)
- Safety (dead man's switch and propeller protection)

Evolo has been divided into four main parts; floating body, underwater body, propulsion and material.

Floating body

According to the requirements specification, the craft must be able to float and balance in a stationary position with the driver and be able to be steered by means of a center of gravity shift. Surveys regarding the target group show that close contact with the water and physical exertion are among the general features that water sports practitioners appreciate. A floating body in the form of a surfboard is easy to associate with these properties and the shape of Evolo's floating body has therefore been chosen to resemble a surfboard.

Evolo's floating body is not 100% designed, but it is clear that it must have a volume displacement of 0.17 m^3 [4]. From tests performed on October 18, 2008 in Saltsjöbaden, several instructive conclusions were drawn about the floating body [3]. Driving position was examined and a kneeling driving position was established as the easiest way to handle Evolo. However, the conceptual design offers two different driving positions; kneeling and standing, as the goal with Evolo is that it should be a challenge to drive, and provide a large space for personal development.

The tests also revealed the need to be able to move the driver's center of gravity quickly. This has meant that the Evolo has been given an upper body with a large surface to facilitate the driver's movements. The surface will also be provided in a suitable place with a soft material as the testers experienced pain in the knees after sitting on the tested model. Requests for a floating body that can be lowered into the water while driving without causing too much resistance were expressed, whereupon Evolo was provided with a slightly larger upper body in the bow with streamlined lines. This is so that Evolo can accelerate more easily and be allowed to "bounce up" if the user presses the bow into the water during use. A slightly larger volume is also required for other reasons such as containing batteries and electronics. The vision is that this volume should also be able to contain a waterproof storage compartment, a clear LCD screen with information about speed, battery level, depth, position, etc., and lanterns.

Evolo is equipped with handles to facilitate controlled driver movement. The experiment has shown that in order to be able to turn the craft around the vertical axis, the driver needs to use fixed points to hold on, which is why the craft is equipped with two handles, one on each side.
These handles have two positions; raised (Figure 36) so that you can stand on the craft and hold on and lowerd (
Figure 37) so that you can sit on your knees. The handles have controls for the engine and dead man's switch. For even greater freedom, you should be able to remove the stays for the handles completely and disconnect the handles, which can then regulate the motor wirelessly.

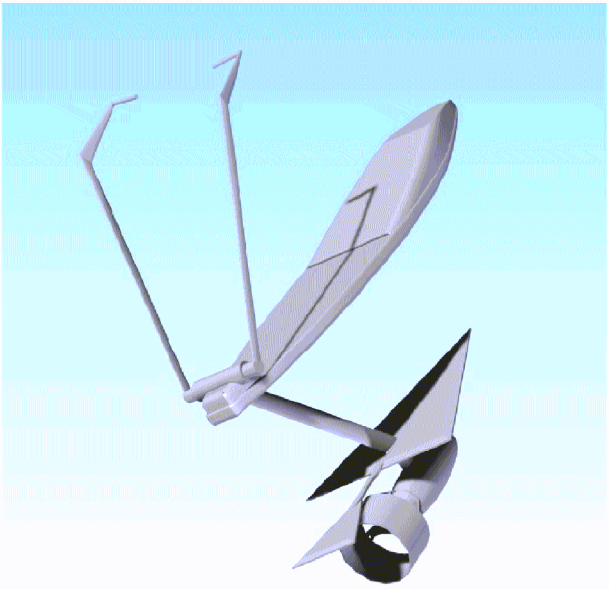


Figure 36: Evolo with raised handles

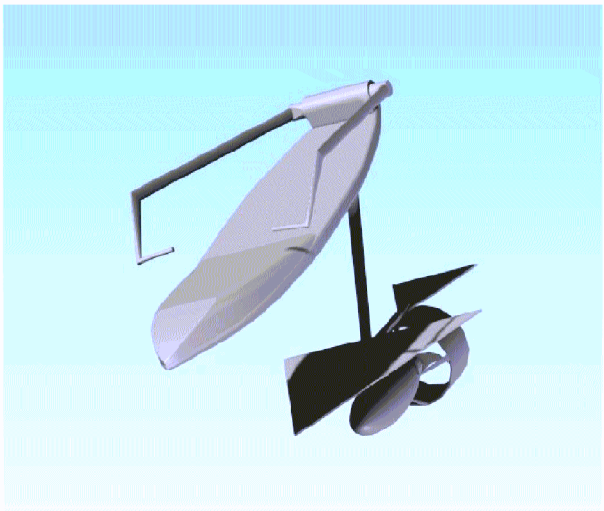


Figure 37: Evolo with lowered handles

Underwater body

The investigation of the design of the hydrofoils has been done in two stages, partly analytically and partly experimentally, and it has been realized early on that two wings are probably required, of which a main wing and a stability wing. Calculations of the main wing have been performed on two different types of wings and have included resistance, size, design and angle of attack. The two investigated types are straight wings and delta-shaped wings. From a resistance point of view, it has been chosen that a straight hydrofoil constitutes the least propulsion resistance. However, the delta wing has analytically proven to be capable of larger angles of attack and that it does not respond as quickly to a disturbance of the angle of attack as the straight wing, which is why the analytical investigation shows that a delta wing is preferable.

Also during the experiment, it was observed that a delta-shaped wing gave increased control and meant that Evolo became less sensitive to small disturbances, so a delta-shaped main wing was chosen for the conceptual design.

According to the analysis, the wings made for the experiment would lift the craft at a speed of about 6 knots This agreed very well with the experiment, which is rumored that the analytical calculations made on the wings that refer to angles of attack and dimensions do not seem to be too far from reality. However, the size and relative position of the wing can not yet be determined exactly as engine power and drag resistance have not yet been determined.

The stabilizing rear wing was experienced during the experiment not to add as much stability as desired, but a certain positive difference was observed with a stability wing slightly inclined forward, regardless of whether it was a straight stability wing or a delta-shaped one.
The stability wing is therefore included in the conceptual design until further investigation has been carried out. See Figure 38 below.

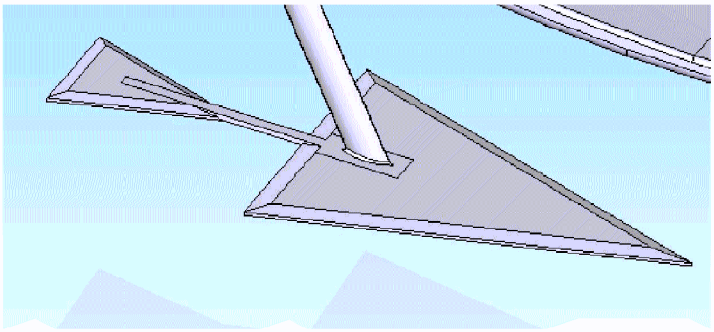


Figure 38. Design of hydrofoil

In order to be able to get the desired stability and turning properties on the Evolo, it must be possible for the user to replace the stability wing. This should e.g. can be adapted to driving style, knowledge and different wave conditions (weather conditions). It is conceivable that a more experienced driver can choose a more fast-swinging craft, while a beginner can choose a slightly more course-stable craft.

The hydrofoil is mounted on the board with a simple stay. The reason for this is to have less resistance in the water, lower weight and a simpler and cheaper manufacturing process. With a simple stay, the Evolo also gets a lighter and smoother expression, and it is angled and tilted forward to give a more aggressive look. The stay has to some extent been analyzed analytically and as a result has been designed as a wing to facilitate its steering and contribute to as little propulsion resistance as possible. During model building, however, the significance of the thickness of the strut was observed. The first strut that was built was perceived as far too sensitive to the torques around the vertical axis that could occur, which is why a much more powerful support was constructed. The lessons are included in the conceptual design and a thicker strut is used unless a material with significantly stronger torsional rigidity can be found. The strut must be able to fold forward during transport and travel in shallow water. [3], [4]

Propulsion

According to the requirements specification, the vehicle must be electrically powered in order to be environmentally friendly, quiet and relatively power-efficient. The advantages of an electric motor are many, including that it easily meets the requirements for noise and environmental impact, and that it has no requirements for exhaust pipes and chimneys and that it is thus relatively easy to use underwater. The motor is

currently located in the load-bearing hydrofoil (see

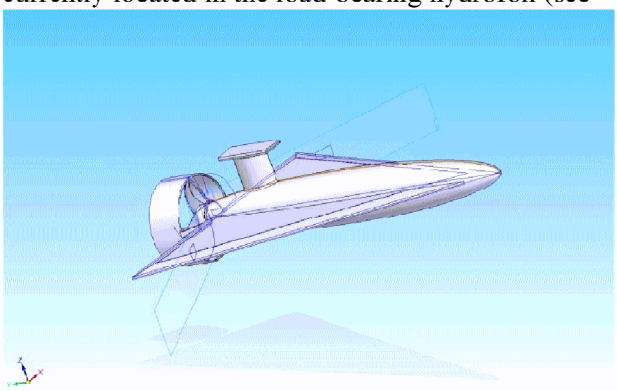


Figure 39) for two reasons. First, the depth and number of components increase if the motor is placed under the wings, and if it is placed over the wings, the number of components increases while the height at which the craft can lift out of the water is reduced. Secondly, the motors front can form the wing for which means that its tip does not become sharp and dangerous to hit if you end up in the water. However, it remains to be investigated how this placement disturbs the flow to the wings and how the installation of the stability wing could look like.

Early in the project, the possibility of using electric water jet drive was studied, but the lack of such motors of the current size on the market meant that the idea was dropped and ordinary propeller operation was chosen. According to the requirements specification, there must be a protection for the propeller, which is why a propeller nozzle is used, but the effects of this remain to be investigated. The motor and propeller are dimensioned only approximately on the basis of existing motors and propellers in the current size class. Something that also remains to be investigated, but which is a wish in the vision is that you can momentarily take extra power out of the motor to be able to jump with the craft, for example.

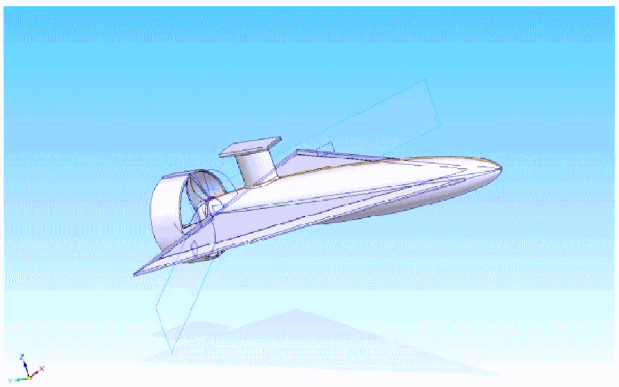


Figure 39: Motor placement

Material

In terms of material on the craft, the weight, the mechanical properties and resistance to moisture are of great importance. Since weight is perhaps most important for this vehicle, the specific E-module as well as the specific strength are important parameters, which is why carbon fiber is a suitable material [5]. High strength and rigidity enable the use of less materials, ie fewer layers of fiber. However, it should be borne in mind that a thin composite layer has poor impact resistance and is therefore sensitive to point forces. This can be solved by using a more impact-resistant material where point forces are likely to occur, e.g. aramid fibers, or use more layers of fiber in these locations. You can also use different types of fibers in the same place in alternating layers.

Together with carbon fiber, a suitable matrix must be used, the most important task of which in this case will be protection against moisture, but it should also have good mechanical properties. A matrix of thermosetting plastic generally has better resistance to the external environment, better mechanical properties and is more practical in manufacture than a thermoplastic. Epoxy and vinyl ester together with carbon fiber are well-proven matrices and with good mechanical properties. However, epoxy is very allergenic in the uncured state and should therefore be avoided.
To save weight, a sandwich solution may also be relevant, especially for the floating body. A possible choice of core is a foam core of a polymeric material that can be made resistant to moisture. As we will not be making large series, vacuum injection is a suitable manufacturing method that also enables more complicated shapes. Another current manufacturing method is hand-laying.

A carbon fiber / vinyl ester composite material is a suitable material system for Evolo. It has good mechanical properties, good resistance to moisture and fits into the "image" that wants to be conveyed with Evolo. These materials are relatively readily available and equipment for manufacturing by means of vacuum injection is also available.

Conclusion

The Evolo craft has been roughly defined and a vision of what it could be has been established. Many basic parts that the project group had poor insight into have been clarified, cutting-edge knowledge has been developed within the group and the goal, to actually be able to build the craft, is in sight. Of course, there is still a lot to investigate for the project to succeed and priority in the project's third phase Preliminary Design, which begins with this submission, is on propulsion, stability and to some extent strength.

References

1. E. Jerilgård and T. Manners: *Målgrupp*, Evolo, KTH, 2008
2. M. Razola: *X3-Rapport*, Evolo, KTH, 2008
3. M. Norberg: *A1-Bärplan*, Evolo, KTH, 2008
4. B.T.Åström, *Manufacturing of Polymer Composites.*

Description of general arrangement
Evolo D4



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Project:	Evolo
Date:	*20/11-2008*
Version number:	*1.0*
Hours worked:	*10*
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Introduction

The purpose of the general arrangement (GA) for Evolo is to describe all the measures used in the various sub-reports. GA will be updated with new measurements as needed. All descriptions of coordinate systems or parameters are shown in Figures 1 and 2.

Coordinate system

Evolo has a local coordinate system (x, y, z) that is defined with the origin in the aft point of the body. the x-axis moves in the longitudinal direction of the ship, the y-axis in the width of the craft and the z-axis vertically.

Parameters

L	The length of the floating body.
T	The floating body deepest depth.
s	The distance from the origin to the foremost mounting point of the strut.
H	Vertical distance between the mounting of the strut in the hydrofoil and the floating body.
c_s	The chord on the strut
c_1	The chord on the front hydrofoil.
c_2	The chord on the aft hydrofoil.
a_1	The distance between the front mounting of the strut in the link arm to the mounting of the link arm on the front hydrofoil, which is attached in the point of attack of the lifting force.
a_2	The distance between the front mounting of the strut in the link arm to the mounting of the link arm on the aft hydrofoil, which is attached in the point of attack of the lifting force.
t_1	The thickness of the front hydrofoil.
t_2	The thickness of the aft hydrofoil.
B	The largest width of the floating body.
b_1	The largest width of the front hydrofoil. b_2 he largest width of the aft hydrofoil.
t_s	Thickness of the strut.
α_1	Front hydrofoil angle of attack.
α_2	Aft hydrofoil angle of attack.
γ	The sweeping of the strut forward, ie. the angle between the z-axis and the support in the xz-plane.
θ	The heeling angle of the craft, ie. the angle between the z-axis and the strut in the yz-plane.
τ	The angle between the floating body and the x-axis in the xz-plane.

Dimensions

The current dimensions are shown in Table 1.

Table 1

Parameter	Length w / degrees	Report	Parameter	Length w / degrees	Report
L	2,3	A12	t_2	0,018	X3
T	0,15	A12	B	0,7	A12
s	0,35	X3	b_1	0,8	A1
H	0,83	X3	b_2	0,36	A13

c_s	0.2	X3	t_s	0.037	X3
c_1	0.87	A1	α_1	10	A13
c_2	0.39	A13	α_2	5	A13
a_1	0	X3	γ	0	X3
a_2	1.1	A13	θ	0	X3
t_1	0.018	X3	τ	0	X3

Verification plan

The idea is that this GA should be updated once every two weeks. When updating, attach the old report as an appendix.

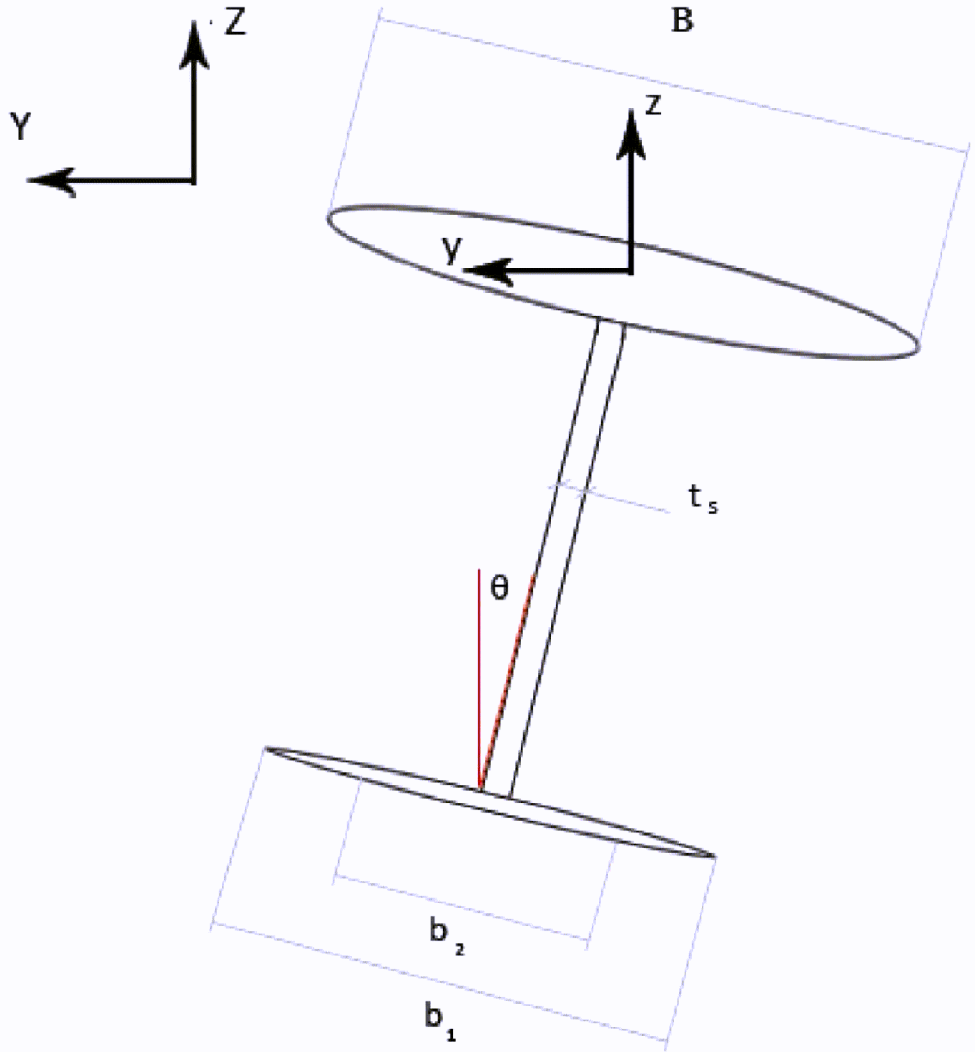


Figure 1. GA from the aft

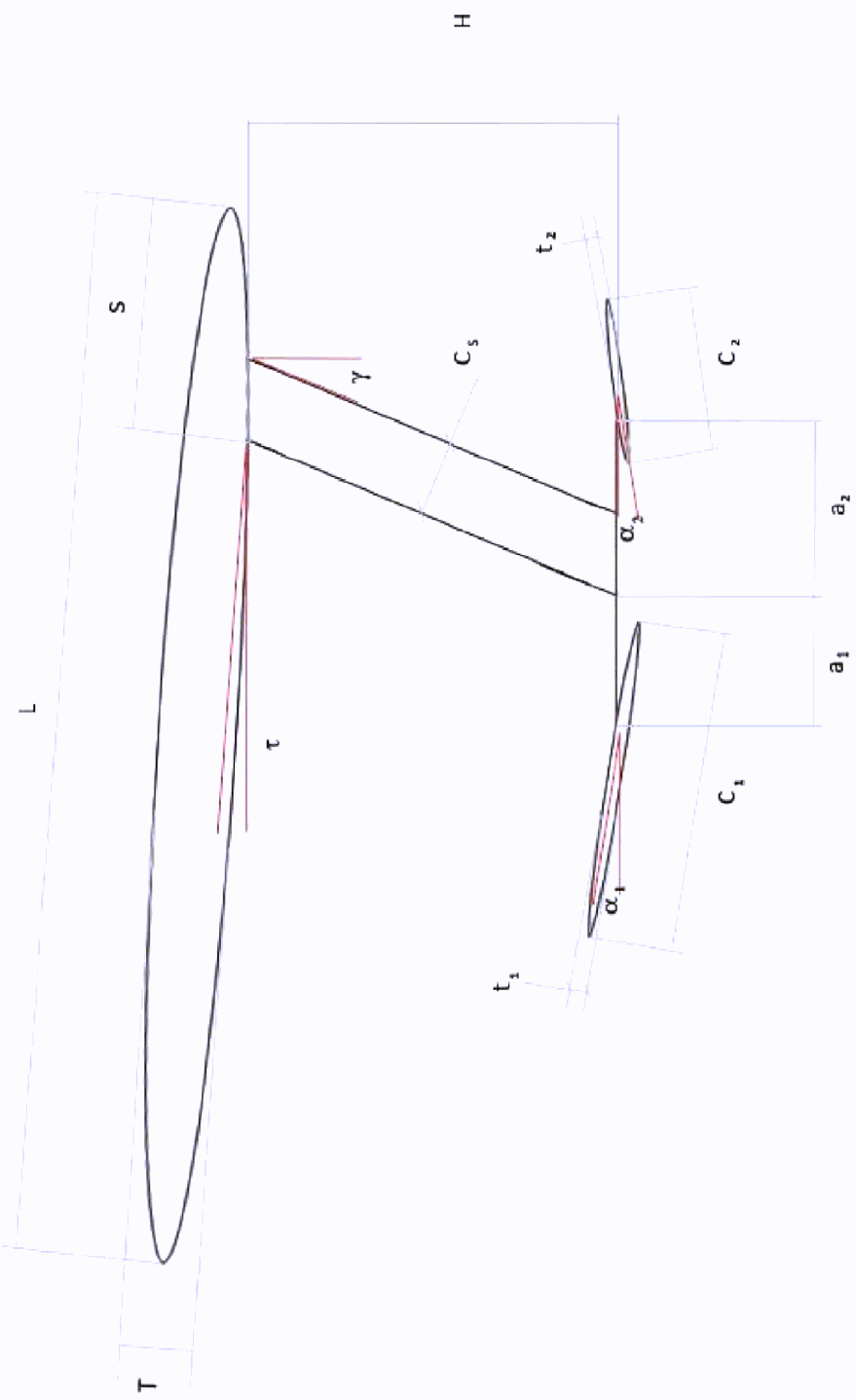


Figure 2. GA from the side

Appendix 1 - Checklist for Quality Assurance

The purpose of the list is to function as a structuring support for planning, writing and proofreading reports and as support for self-reflection. The list should be used for feedback from proofreaders. Evaluate each point with yes / no and sometimes with a grade of u, 3,4,5. Note that the completed checklist must be attached to each report!

General impression	Author Yes/No	Reviewer Yes/No
375. Are all elements of the problem addressed?	Y	YY
376. Have the purpose and conditions been reported?	Y	YY
377. Have relevant conclusions for the benefit of the project been drawn, reported and related to the objective?	Y	Y
378. Is the purpose achieved?	Y	YY
379. Is the report readable without access to task formulation, project instructions, etc. that you have received from teachers and supervisors?	Y	YY
Technical content		
380. Have simplifications and assumptions been clearly stated and justified?	Y	Y
381. Has the choice of solution methods been clearly reported and justified?	Y	Y
382. Are calculations controlled and reasonably assessed?	-	--
383. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	Y	YY
384. Are equations written as part of the running text, presented in separate lines and numbered?	-	--
385. Can the technical reasoning be followed?	Y	Y
386. Is there a difference between facts, statements and the author's opinion?	-	--
387. Is there a realistic verification plan for the work in the report?	Y	Y
388. Is there an acceptable follow-up of the verification plan?	Y	Y
Presentation		
389. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	Y	YY
390. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor,summary/abstract, table of contents, reference list and page numbering	Y	YY
391. Is the report written in third person passive form? Are experiments described in imperfect, e.g."Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?	Y	YY
392. Are figures and tables clear and informative, provided with figure / table text and clear numbering? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black and white copying?	Y	YY

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393. Are appropriate references made to figure, table and equation numbers in the text?	Y	YY
394. Are appropriate references made to references in the reference list?	-	--
395. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Y	YY
Other		
396. Has the report been written by you individually? By the authors.	Y	
397. The work has been carried out in collaboration with: _____		-
398. The report has been proofread by: Torvald Manners and Fatima Ekekrantz		-

D5 - Ergonomics Evolo

ERIK JERILGÅRD
MATTIAS KENNESTAD

Course:	Marine design / Lightweight design
Project:	project name
Date:	*25/11-2008*
Version number:	*1.0*
Hours worked:	*11*
Reviewed by:	Fatima Ekekrantz and Markus Norberg

Summary

In order for Evolo to be comfortable, safe and easy to maneuver, the ergonomics of the vehicle have been evaluated. The investigation has been developed with the help of the lessons learned in the full-scale experiments and then the model for the placement of the handles has been developed via experiments in the workshop. Figures of the size of the handles and the relative position of the standing and kneeling driving position, respectively, are shown in Figures 1, 2 and 3 and are summarized in Table 1. These dimensions have been developed and tested for a driver with a length of between 160 and 195 cm. The height and width of the handles were chosen to provide a comfortable and versatile driver position and to be able to have a gentle angle on the back and neck when driving. The tests also show the importance of padding the top of the Evolo to avoid injuries to the driver's knees and that it is very important to be able to move quickly on the vehicle without losing grip on the handles and that the driver must stand relatively wide-legged to keep his balance in the best way.
The report also provides suggestions on how the handles could be designed for both kneeling and standing driving position.

Analysis

The analysis begins with the various drivers' experiences of the trials being summarized to see which details are perceived to be in need of change and what should be considered when designing handles for the craft. What is particularly pointed out is that the craft is very hard on the upper side and that this leads to pain in the drivers' knees when in use. Next, it is examined which size and location for the handles is preferable for people between 160 and 195 cm in length. This is done by placing the prototype in the lab while the different testers test different placements of test handles. Factors that are considered are convenience and the ability to maneuver the craft as well as safety. The driver positions examined are standing and kneeling according to Figures 4 and 5 and Table 1. Further inspiration for the design of the driver's positions has been sought on the Internet and is summarized in Figure 6.

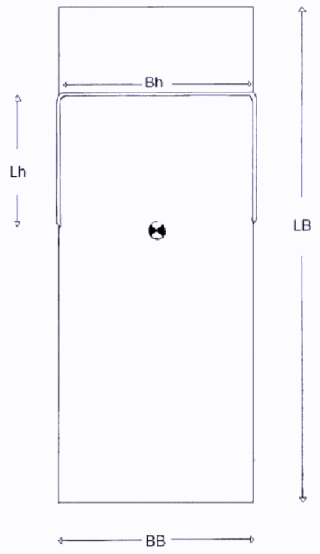


Figure 13. Simplified view of Evolo from above with handle for kneeling operator position.

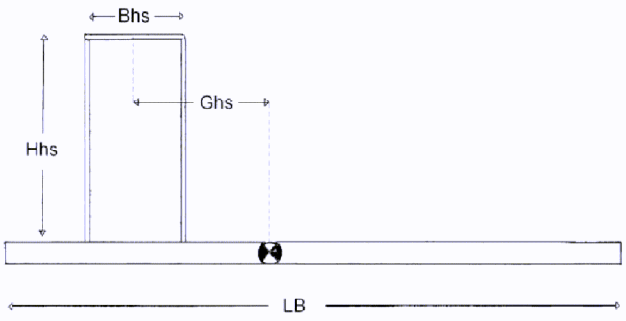


Figure 14. Simplified view of Evolo from above with handle for standing operator position.

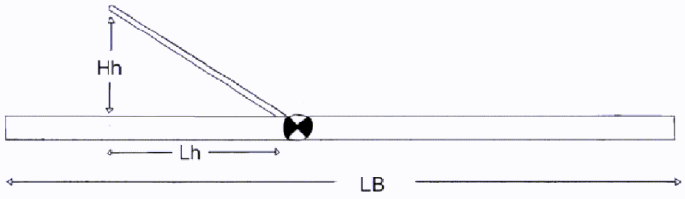


Figure 15. Simplified side view of Evolo with handle for kneeling operator position.

Table 1. Values of parameters according to Figure 1, 2 and 3.

Parameter	Value
Hh	30 cm
Hhs	60-90 cm
Bh	70 cm
Lh	45 cm
Bhs	30 cm
LB	230 cm
BB	70 cm
Ghs	45 cm

The horizontal distance from the driver's center of gravity to the center of the handle in the standing driving position, *Ghs*, is 45 cm. In the kneeling driving position, the driver's center of gravity is placed approximately at the height of the handle's aft mounting in the floating body according to Figure 3. The handles for standing driving position are 2 pieces and are placed at the outer edges of the floating body so that the driver can fall in the direction of travel if he or she falls.

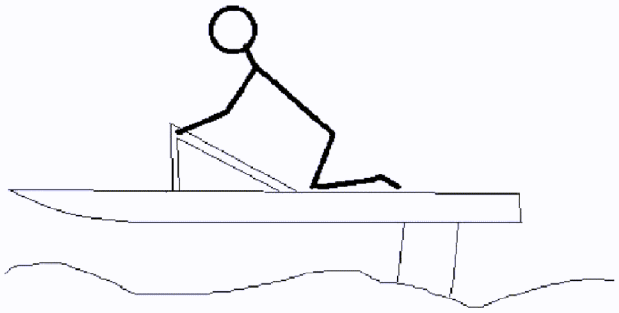


Figure 16. Kneeling driving position.

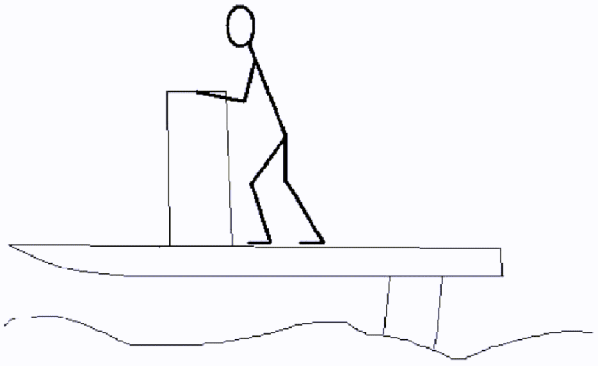


Figure 17. Standing driving position.



Figure 6. Inspiration pictures for different driving positions and handle designs.

Handle design

The simplest and safest is deemed to be to only design the handle solution by Evolo for the kneeling driving position as in Figure 4. With fixed handles for the standing driving position, they are likely to get in the way of the driver in the kneeling driving position and may pose a safety hazard in the event of a crash.

In order to design a handle solution as described in Evolo's conceptual design [1] for a standing riding position, it should be able to be folded down, either as described in [1] or with a telescoping bar. In order for the maneuvering of the craft not to be difficult, it is required that the handles for the standing driving position must be sufficiently rigid. It can be investigated in further experiments what sufficiently rigid means in this context. Handles for the kneeling driving position are considered to be permanently mounted, but do not necessarily have to be if there is a good solution for a removable system that can be used for both kneeling and standing driving positions.

Conclusion

The dimensions given in Table 1 should be used when constructing the handles on the Evolo and the top surface should be soft to protect the rider's knees. For the kneeling driving position, handles can be permanently mounted, but for the standing driving position, the handles should be able to be folded away or folded.

References

1. Sattari Far J, H, Wolter, N, Westlund, J, Carlsson, D Norberg, M, D1 - *Konceptuell design för studentprojekt* Evolo. KTH, 2008.
2. Various Internet pages via Google image search.

Appendix 1 - Checklist for Quality Assurance

The purpose of the list is to function as a structuring support for planning, writing and proofreading reports and as support for self-reflection. The list should be used for feedback from proofreaders. Evaluate each point with yes / no and sometimes with a grade of u, 3,4,5. Note that the completed checklist must be attached to each report!

General impression	Author Yes/No	Reviewer Yes/No
399. Are all elements of the problem addressed?	Yes	Yes
400. Have the purpose and conditions been reported?	Yes	Yes
401. Have relevant conclusions for the benefit of the project been drawn, reported and related to the objective?	Yes	Yes
402. Is the purpose achieved?	Yes	Yes
403. Is the report readable without access to task formulation, project instructions, etc. that you have received from teachers and supervisors?	Yes	Yes
Technical content		
404. Have simplifications and assumptions been clearly stated and justified?	Yes	Yes
405. Has the choice of solution methods been clearly reported and justified?	Yes	Yes
406. Are calculations controlled and reasonably assessed?	-	Yes
407. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	Yes	Yes
408. Are equations written as part of the running text, presented in separate lines and numbered?	-	-
409. Can the technical reasoning be followed?	Yes	Yes
410. Is there a difference between facts, statements and the author's opinion?	Yes	Yes
411. Is there a realistic verification plan for the work in the report?	-	-
412. Is there an acceptable follow-up of the verification plan?	-	-
Presentation		
413. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	Yes	Yes
414. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor,summary/abstract, table of contents, reference list and page numbering 415. Is the report written in third person passive form? Are experiments described in imperfect, e.g."Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?	No content, E-mail Yes	No Yes
416. Are figures and tables clear and informative, provided with figure / table text and clear numbering? numbered? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black and white copying?	Yes	Yes

417. Are appropriate references made to figure, table and equation numbers in the text?	Yes	Yes
418. Are appropriate references made to references in the reference list?	Yes	Yes
419. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Yes	Yes
Other		
420. Has the report been written by you individually?	Us, yes	-
421. The work has been carried out in collaboration with: _____		-
422. The report has been proofread by: Fatima Ekekrantz and Markus Norberg		-
423. I believe that this report as a whole is worth rating (u, 3-5)		4
424. The following is a reflection on how I believe that the work with this report and related projects relates to set learning goals (relevance of the work, which goals have been met, etc.): Lacks introduction with purpose and problem formulation, otherwise good report / Fatima and Markus		-

FEM modeling



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Course:	Lightweight design
Project:	Evolo
Date:	*3/3-2009*
Version number:	
Working time	50 hours
Reviewed by:	Fredrik Bender

Introduction

The purpose of this report is to investigate the thickness of the core material as well as the number of layers of carbon fiber composite and the frequency of laying this. This is done using the FEM program Abaqus. Material data is taken from *TB104 VI Drag Resultat* and http://www.diabgroup.com/ (core material manufacturers), see *Table 1*. Divinycell H45 is used as the core material partly because it is available and because the core in the floating body has to be thick and it is therefore advantageous to have a lighter core material. Load cases are taken from *A17_Maximala_Belasningar_I_Strukturen* [2].

Table 1. Material data.

	Carbon fiber composite (IM)	Core material (Divinycell H45)
Thickness [mm]	0.2	-
E_1 [GPa]	151	0,055
E_2 [GPa]	9.4	0.055
G_{12} [GPa]	4.8	0.015
ν_{12}	0.31	0.3
$\sigma\hat{}1t$ [MPa]	2260	1.4
$\sigma\hat{}1c$ [MPa]	1200	0.6
$\sigma\hat{}2t$ [MPa]	50	1.4
$\sigma\hat{}2c$ [MPa]	190	0.6
$\tau\hat{}12$ [MPa]	100	0.56

Floating body

Simplifications of the model are made to facilitate the construction of the model in Abaqus, these simplifications are assumed not to significantly affect the result. See *Figures 1* and *2* for dimensions. The mounting point of the strut is currently not determined and therefore it is placed far back on the model to represent the largest load case. The load is varied between 4000 N and 500 N to see what happens in different load cases. The point of attack is also varied between the three circles, see *Fig. 1*, and is assumed to be an evenly distributed pressure force. The mounting of the strut is locked in all six degrees of freedom (firmly clamped) along the edge of the ellipse, see *fig. 2*.

The core of the floating body is already relatively thick because it must provide buoyancy and accommodate various components, e.g. batteries. Changes to this thickness will therefore not be made, but only the fiber arrangement will be varied.

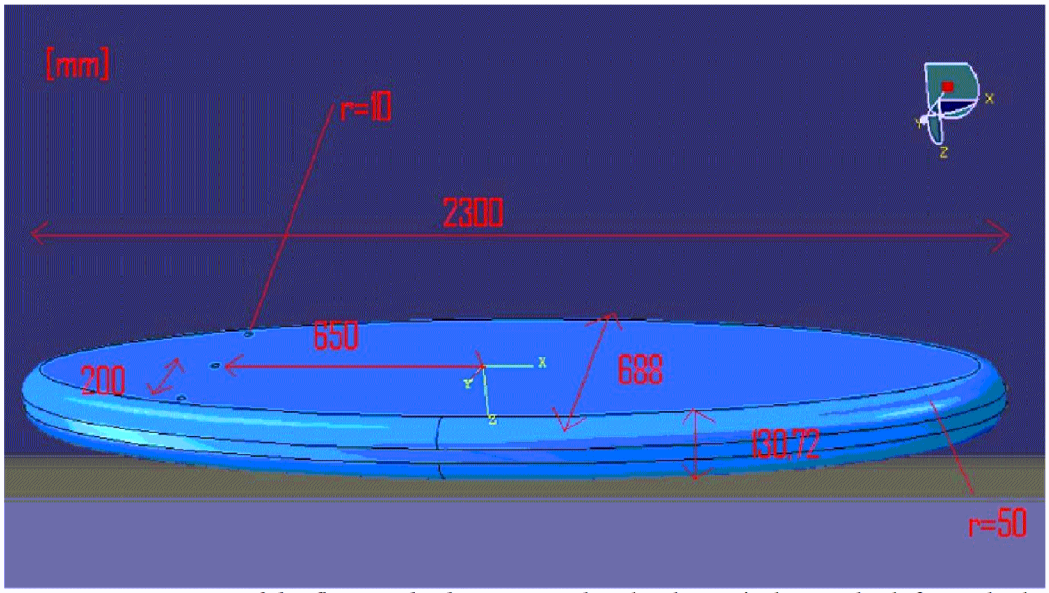


Figure 1. Dimensions of the floating body, upper side. The three circles on the left are the load points.

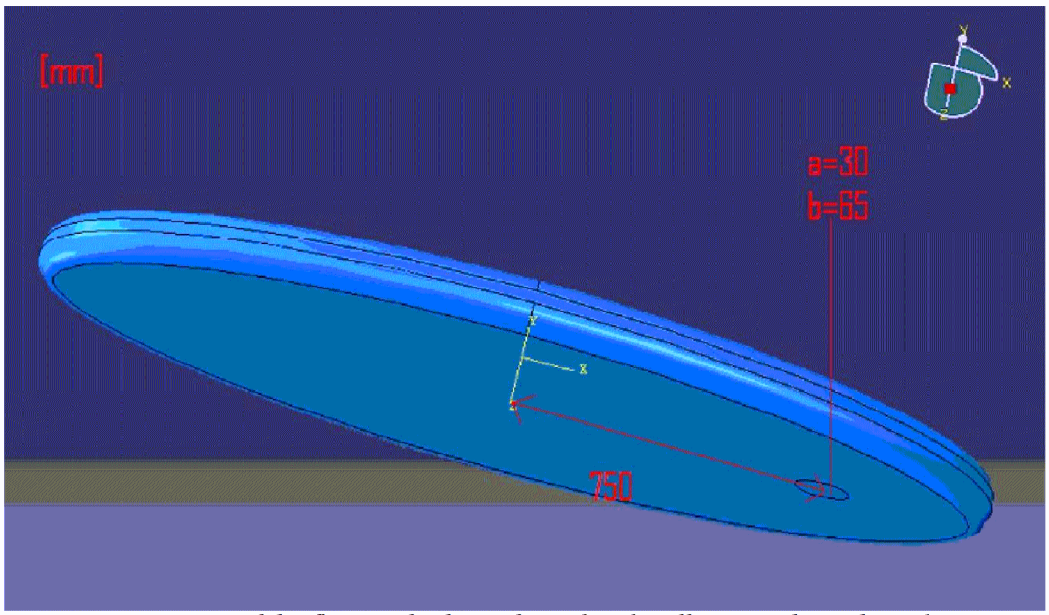


Figure 2. Dimensions of the floating body, under side. The ellipse on the right is the mounting.

Results

The deflection for a load of 4000 N at the middle load point is reported in *figure 3*. A comparison can be made with *Figure 4* where the point on the right is loaded. The fiber layout in all figures is (0/45/-45).
The displacements are in mm and the stresses in Mpa.

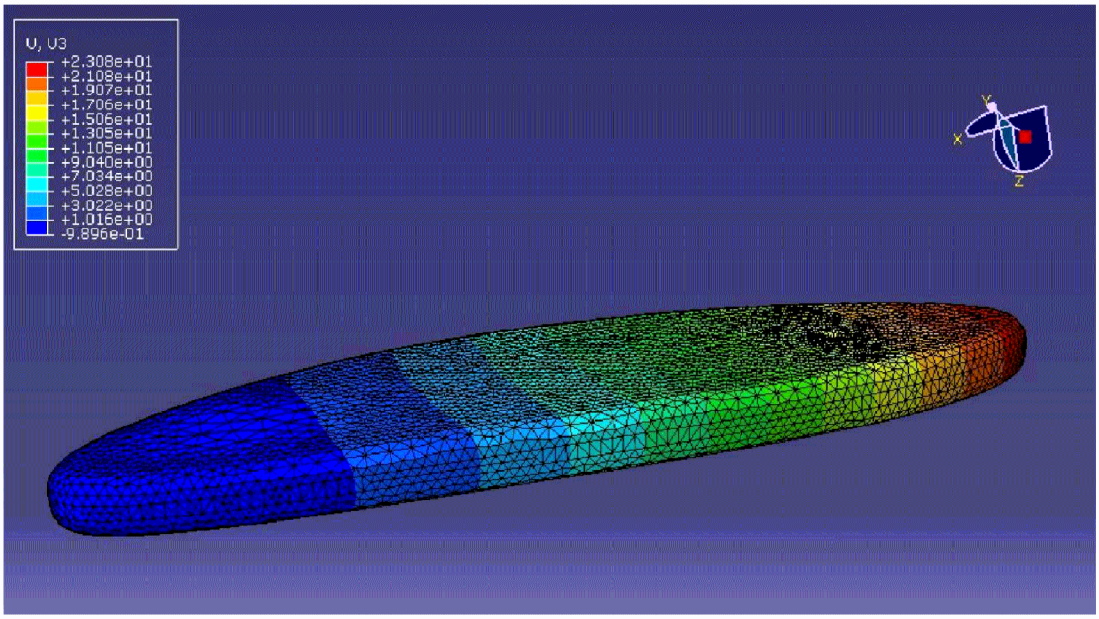


Figure 3. 4000 N loads the point in the middle.

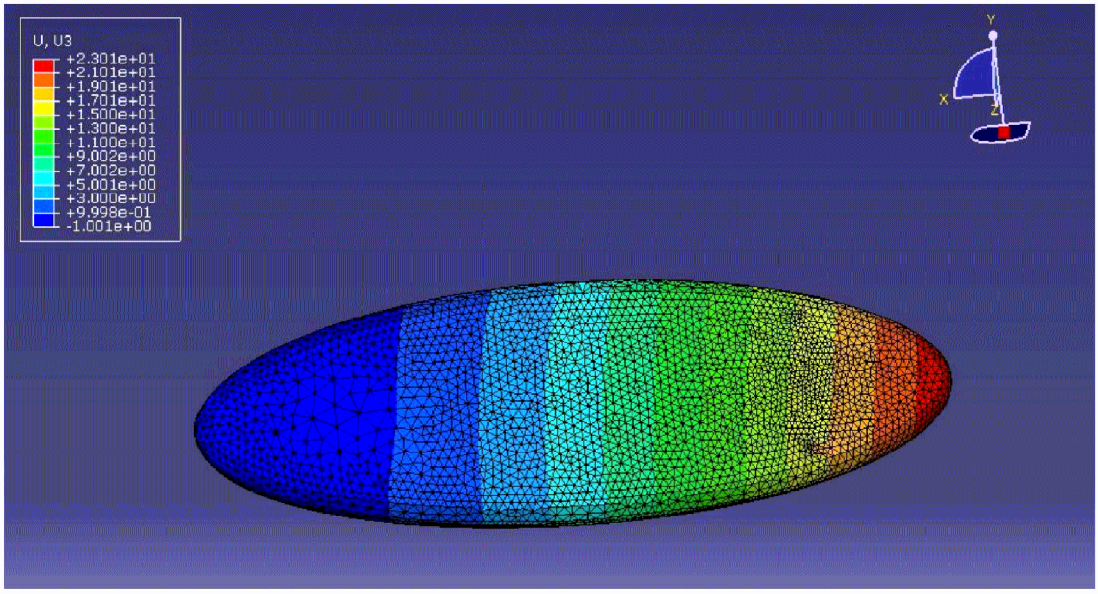


Figure 4. 4000 N loads the point on the right.

In F*igure 5*, all three load points are loaded with a total load of 1000 N. In *Figure 6*, only the point on the right is loaded with 1000 N.

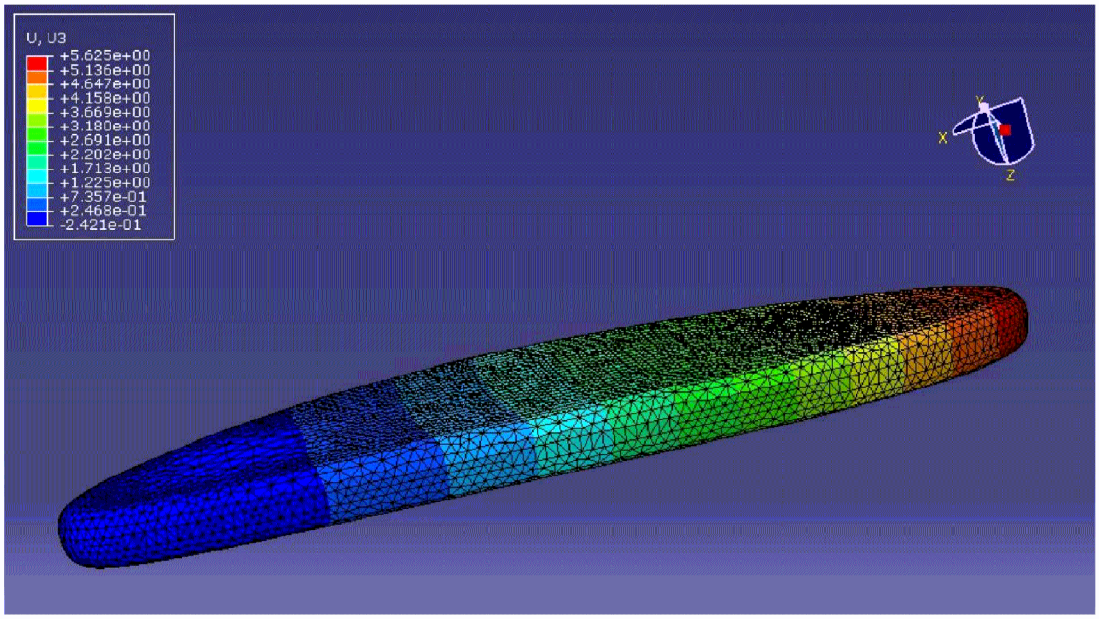


Figure 5. 1000 N distributed on all three points.

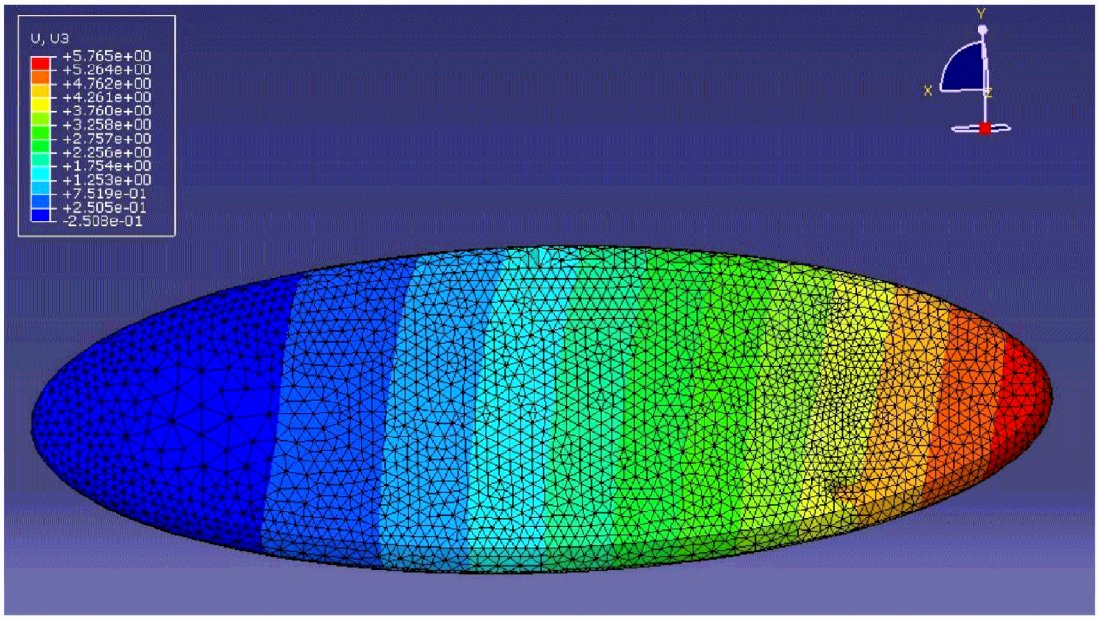


Figure 6. 1000 N loads the right point.

Figure 7 shows the stresses in the mounting for a load case of 4000 N. *Figure 8* shows the stresses in the load point.

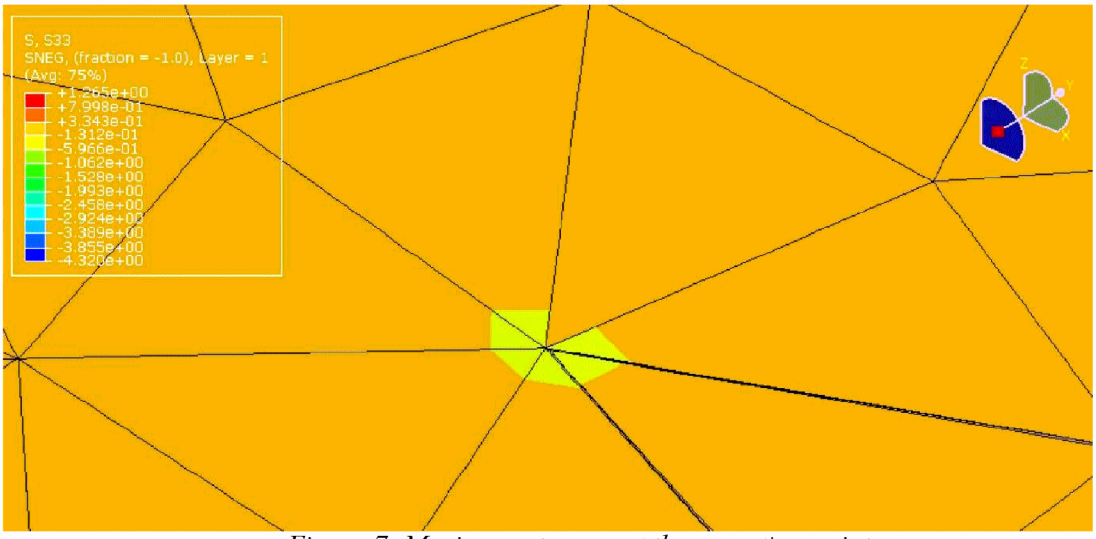


Figure 7. Maximum stresses at the mounting point.

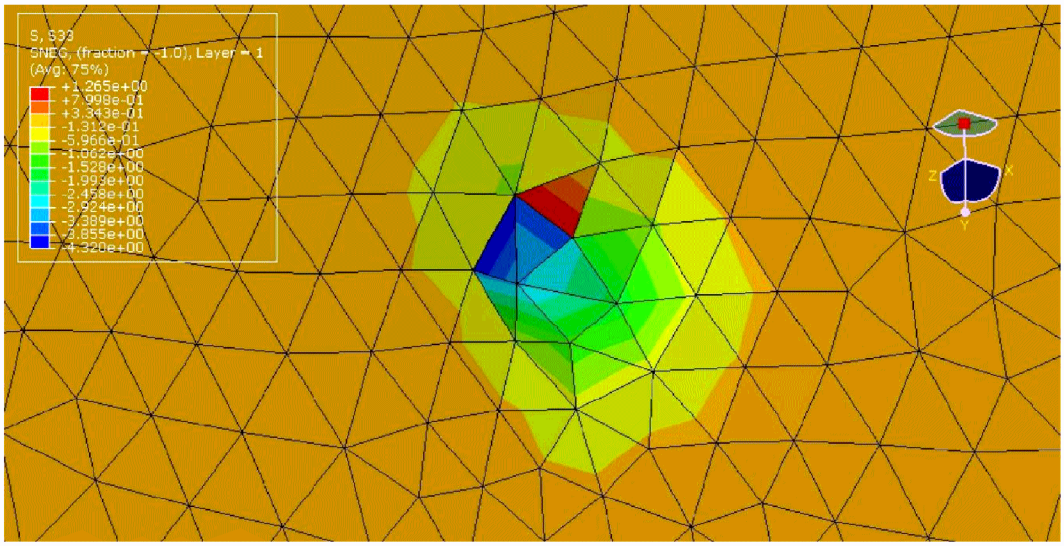


Figure 8. Maximum stresses at the load point.

Figures 9, 10 and *11* show the shear stresses for the same case.

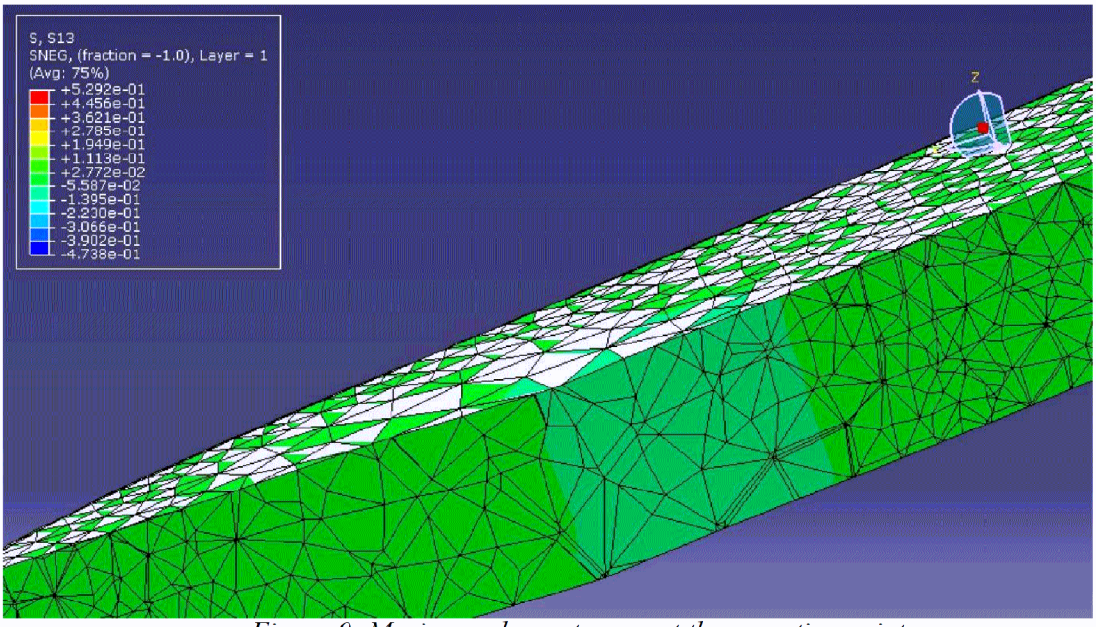


Figure 9. Maximum shear stresses at the mounting point.

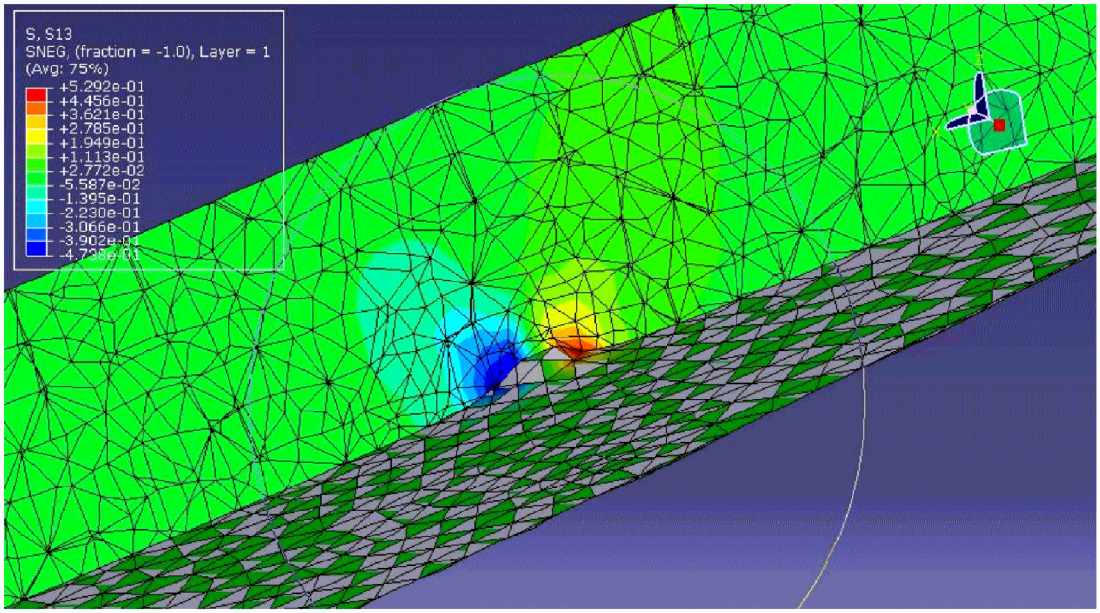


Figure 10. Maximum shear stresses at the load point (xz plane).

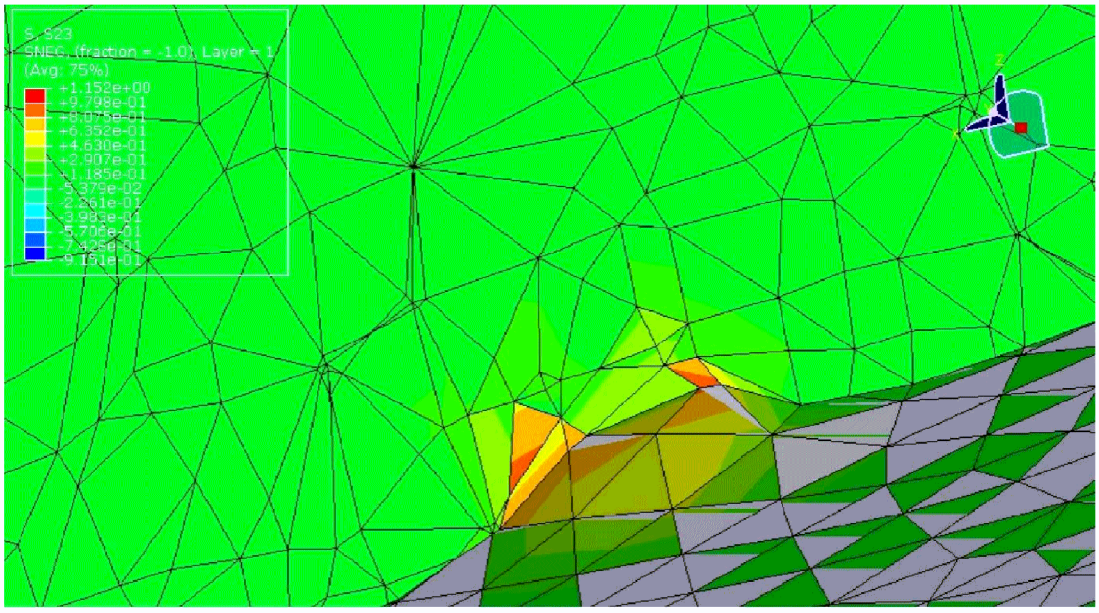


Figure 11. Maximum shear stresses at the load point (yz plane).

Table 2 summarizes the maximum deflection for different load cases.

Table 2. Maximum deflection [mm] for different load cases.

Fiber layout / Load case	4000 N, middle	4000 N, right	1000 N, all	1000 N,right	500 N, all
(0/45/-45) (0/45/0/-45)	23.1	23.1	5.6	5.8	2.8
	15.1		3.7		1.8
2pc. (0/45/0/-45)			2.0		

Discussion and conclusion

In the figures above, you can see that the stresses are low at all points on the floating body except at the load points and the mounting point. However, these stresses are lower than what the composite material can handle, but can become critical for the core material. Therefore, some form of reinforcement of the core material at these points is recommended.

The maximum displacements (at the far end of the board) become high for the load case with 4000 N. This load case is intended to simulate a "crash" and is considered well measured. In addition, in all load cases, the strut is placed far back on the floating body, it will probably be further forward, which results in less displacement.

The displacement depending on the point of attack of the load does not differ very much between the different load cases for a fiber layout of (0/45/-45). Since the stresses are not critical except at the load and mounting points, the displacements become dimensional. A decision on acceptable displacement should be made with the whole group, possibly with the project manager.

Strut

Some simplifications of the strut geometry have been adopted to facilitate the creation of the model in Abaqus. Since the real strut has a wing profile shape, it has been modeled as an ellipse, see figure 12, where the two radii of the ellipse correspond to the length and thickness of the wing profile. The size of the core is fixed and what must be varied is the thickness of the surface layer. Since there will be room for a pipe with cabling in the strut, a hole for it is also included in the model. The length of the strut from float to engine bulb is currently set to 83 cm, which is also the case in this model.

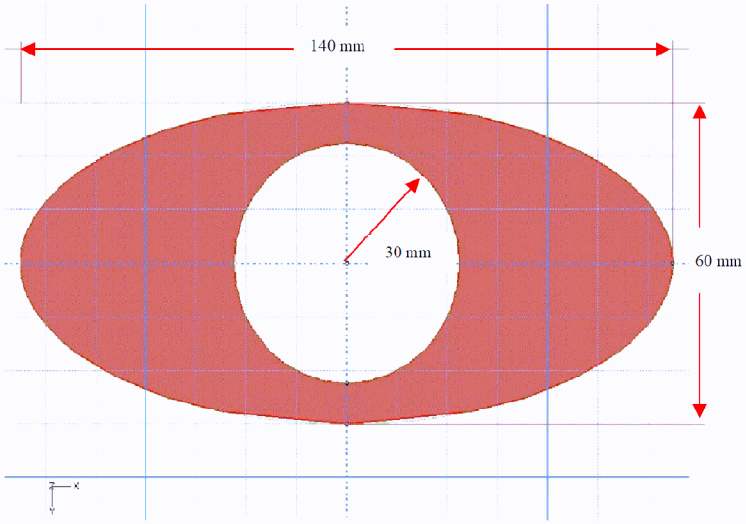


Figure 12. A cross-section of the modeled strut with measurements.

The load cases used in the model are those from *J.Westin and N.Wolters A17_Maximala_Belastningar_I_Strukturen* and can be seen in *figure 13* where the same boundary condition is also used, fixed in tension. The vertical force is applied as a surface pressure on the strut while the moment and the horizontal force are applied to the edge of the ellipse at 50 discrete points. At the end of the strut where the forces are applied, an aluminum shell is modulated to get smaller displacements from the discrete load points. This shell does not significantly affect the results, but only makes it more visible as they remove high stress areas in the model.

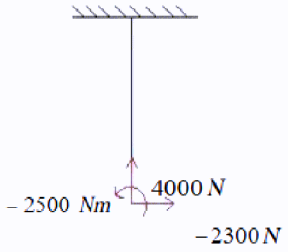


Figure 13. The developed load case for the strut used in this analysis.

The model is then tested for the given load case with different numbers and different fiber directions until a good configuration is found. The fiber directions analyzed by the process were [0 0], [45 -45 -45 45],[0, 45, -45, -45, 45 0], [0, 0, 45, -45, -45, 45, 0, 0] och [0 0 0 45 -45 -45 45 0 0 0]. Each layer has a thickness of 0.35 mm, so the choice of fiber layout will give the thickness of the cover layer.The criteria that the cover layer has chosen to be governed by are deflection and stresses. The stress is controlled by the Tsai-Hill criterion which is a form of absolute amount of the stresses in the cover layer.

Results

The results presented come from a line on the lower part of the strut where we have the most compressive stress. This is because it is this stress that is most critical, the fibers withstand less pressure than stress. The deflection for the different cases can be seen in table 3 and in figure 14 the deflection for the fiber direction is seen
[0 45 -45 -45 45 0].

Table 3. Deflection for different fiber layouts

Fiber direction	Deflection [mm]
[0 0]	24
[45 -45 -45 45]	90
[0 45 -45 -45 45 0]	18.5
[0 0 45 -45 -45 45 0 0]	9
[0 0 0 45 -45 -45 45 0 0 0]	6.8

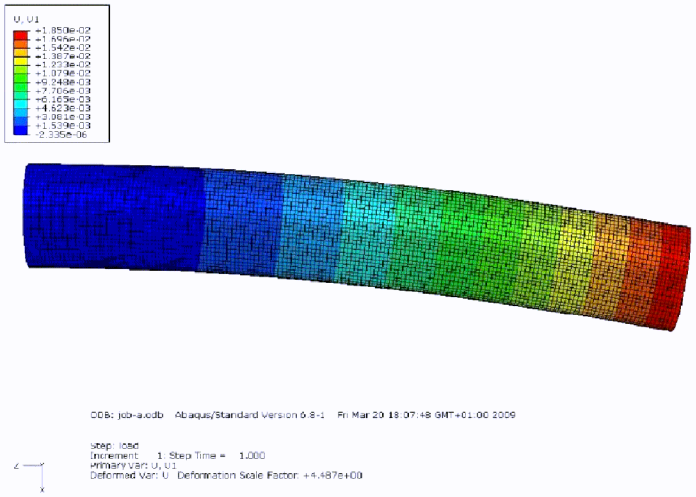


Figure 14. The deflection of the strut when the fiber directions are [0 45 -45 -45 45 0].

The stresses are checked by plotting the relationship between the Tsai-Hill criterion and the ultimate stress against the length of the strut, i.e. when the ratio is 1 the material breaks and if it is less than one it holds. *Figure 14-19* below shows this plot for all fiber directions.

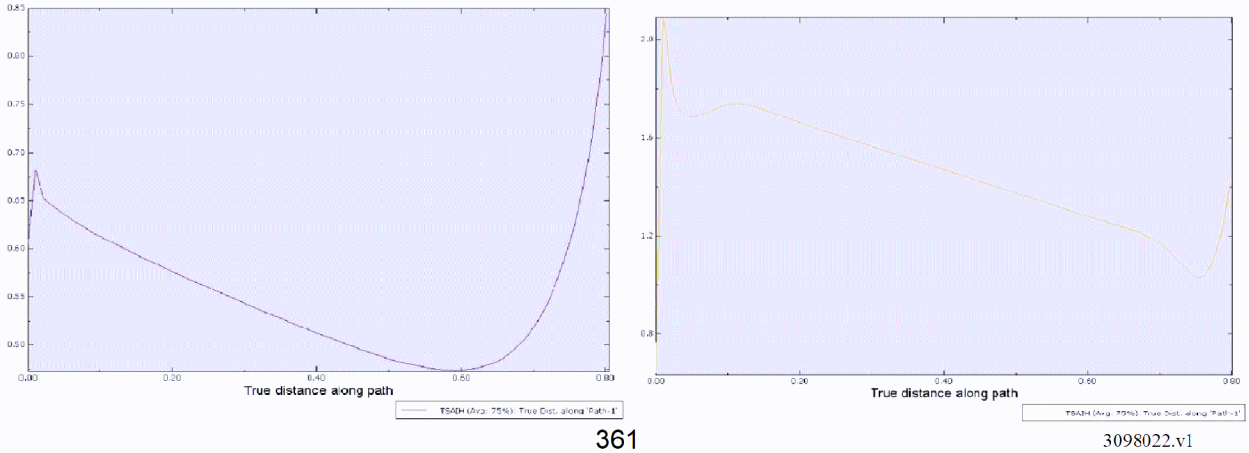


Figure 15. Tsai-Hill criterion for the fiber direction [0 0].

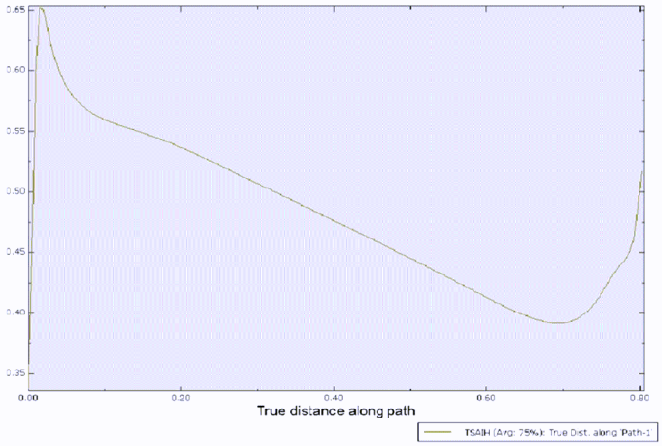


Figure 16. The Tsai-Hill criterion for the fiber direction [45 -45 -45*45*]

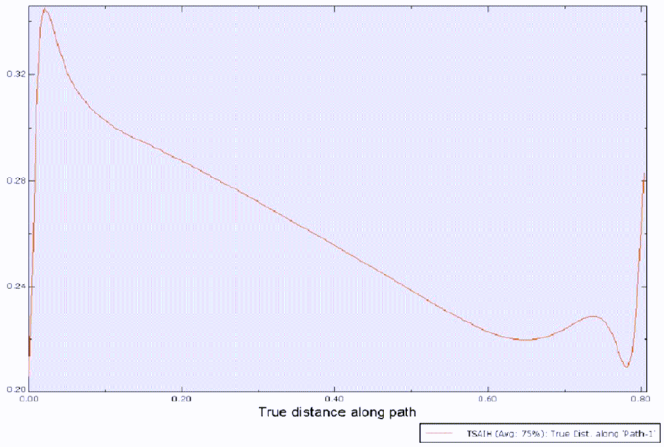


Figure 18. Tsai-Hill criterion for the fiber direction [0 0 45 -45 -*45 45 0 0*].

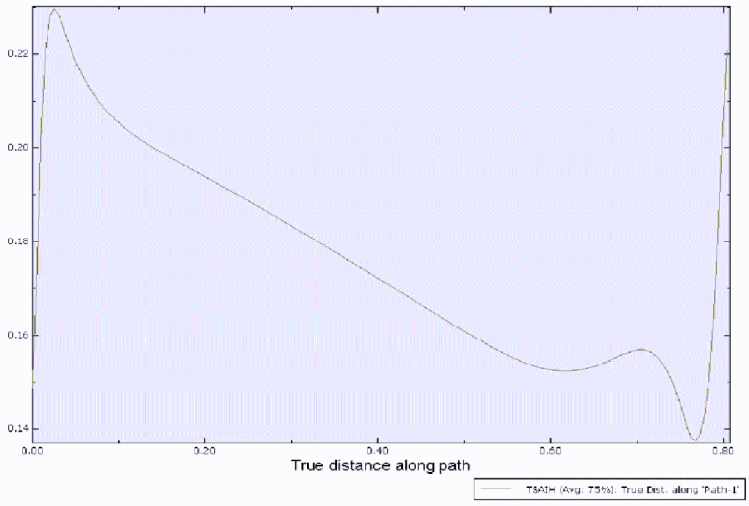


Figure 19. Tsai-Hill criterion for the fiber direction [0 0 0 45 -45 -45 *45 0 0 0*]

As seen, all configurations except the one with only ±45 directions hold.
One of the fiber directions has been investigated with other load cases, this to see how the result changes when the load is reduced. The fiber direction that has been further investigated is [0 45 -45 -45 45 0] and the loads in the used load case have each been halved in two steps. Deflection can be seen for the different loads in *table 4* and the plot of the Tsai-Hill condition can be seen in f*igure 20-22*.

Table 4. The deflection for the selected fiber layout with different load cases.

Factor by which the forces are divided	Deflection [mm]
1	18.5
2	8.4
4	4.7

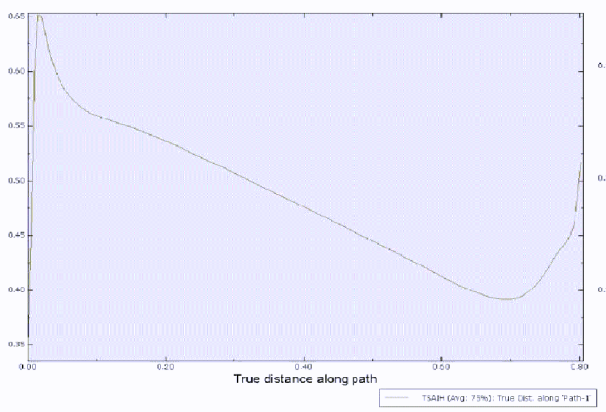


Figure 20. Tsai-Hill criterion for the fiber direction [0 45 -45 -45 45 0] with unmodified loads.

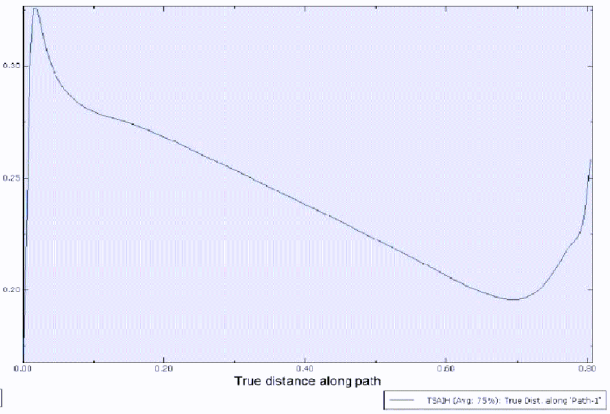


Figure 21. Tsai-Hill criterion for the fiber direction [0 45 -45 -45 45 0] with halved loads.

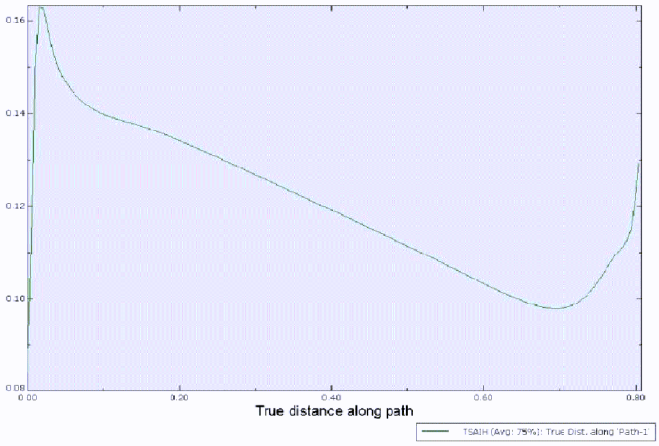


Figure 22. The Tsai-Hill criterion for the fiber direction [0 45 -45 -45 45 0]with a quarter of the original load case.

Discussion

The load case used in the model is intended to be an extreme case when the Evolo crashes. The speed then used was 15 knots. It is now not obvious that Evolo will go at that speed, but rather is adapted to go at 10 knots, which means that this load estimate has a built-in safety factor.
At the ends of the strut, a high factor is obtained on the Tsai-Hill condition, i.e. high stresses. The ends will look different depending on how the mounts look. The idea is that the mountings should relieve the stresses, which allows us to ignore these high stresses at the ends. It can be seen that fibers in the zero direction perform better than fibers in the ±45 directions, but what is not taken into account is that there will be twisting forces on the support where the ±45 directions work very well. The fiber layouts chosen have symmetry around the center line of the cover layer, which is important to avoid internal stresses in the composite when it hardens. In choosing one of these fiber layouts, the stresses has first been checked and then deflection has been investigated to see if it is reasonable.

Conclusion

The fiber layout that is chosen is [0 45 -45 -45 45 0] and then gives a total thickness of the surface layer of 2.1 mm This determined from the fact that symmetry around the center line is needed and that directions in ±45 directions are desirable to take up twisting forces. However, only fiber directions in ±45 are too bad as seen in *figure 16*, but with only two more layers in the zero direction results are obtained with a safety margin of approximately 2, see *figure 17*. In *figure 19-21* it can be seen that the stress decreases linearly with the load, which is reasonable. These lower loads are more realistic to occur during running with the Evolo and the deflections in these cases are acceptable.

PM
M103-Surface layer



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Course:	Marine design
Project:	Evolo
Date:	*2009-04-27.*
Version number:	*1*
Supervised by:	Stefan Hallström, Per Wennhage
Hours worked:	10 h
Reviewed by:	Anders Lundell

Problem formulation / Task / Introduction

This report will report which different surface layers can be used on Evolo. This is done to get a better finish and a surface with less surface roughness on the hull and underwater body. A recommendation for which surface treatment to be used will be given.

Option

When it comes to composite laminate finishes that can be used in the construction of Evolo, there are a handful of options.

On the one hand, there is gelcoat and on the other hand topcoat, which are largely the same thing, the difference between these is when they are applied. The gelcoat applies in a negative form, thus requiring a form to be available. The topcoat is applied to the finished laminate. The coat is moisture and UV resistant. It is usually pigmented. This type of coating is widely used in the small boat industry. The gelcoat is usually applied with a thickness of between half a millimeter and one millimeter

There is also a type of surface treatment called top-sheet, which means that a plastic film is laminated as an outermost layer. However, this is mainly for getting a good finish. This is not UV resistant and it may happen that it delaminates.

The matrix can also be used as a kind of surface layer. You then have a slightly thicker layer of matrix before the fibers arrive. This means, if a transparent matrix is used, that the fibers become visible. Which can be aesthetically attractive.

Another option is to putty on the finished laminate. When this is done, a polyester-based putty is usually used. When it comes to these putty types, there is a plethora here as well. What differentiates the putty types is that they provide slightly different properties. There are lightly sanded fillers, those that provide a pore-free surface and general quick-hardening types of filler.

The last option is to varnish the laminate. This will, if it works, mean a relatively time-consuming process, as many layers of varnish will probably be needed. Here, the number of layers of varnish can be reduced if you can sand the laminate before it is varnished. However, this means that the laminate must withstand the fibers in the outermost layer being able to be sanded. Thus, the laminate must be dimensioned so that damage to the outermost fibers does not cause the construction to fail. An option to sanding is to use a special type of fibers in the outermost layer that gives a better finish. This type of fiber is available in the lab. The varnishing of Evolo must be tested on a laminate that has the same lay-up and matrix as the final product. If it is possible to varnish the test piece, it will with great certainty also be possible to varnish the final product.

Recommendation / Conclusion

The best options for Evolo are believed to be to either paint or to putty and then paint. Here varnish is preferred because that the hype factor for Evolo becomes greater with a clear finish that makes the fine carbon fiber shine through. If it turns out in the trials that varnish does not work, it is suggested that

putty is used followed by varnish. This is because it is considered unnecessary to treat Evolo for a lifetime since it will only be used for less than one season. Thus, a test piece for the laminate must be manufactured and varnish procured. It is suggested that the varnish be purchased from a paint shop. This is preferably done after advice on what type of varnish is to be used. During the experiments to investigate whether the varnish works, it is suggested that the surface of a piece is sanded before varnishing to see if the finish is better or worse than without sanding.

Appendix 1 - Checklist for Quality Assurance

This list is a support so that you don't miss anything in your PM. Only include it in the unreviewed version. Your reviewer is expected to give you feedback after that and then you are responsible for ensuring that all elements are included and any corrections made. Some of the points probably do not apply to your PM, in which case you just mark with a line in that box.

Note that the completed checklist must be attached to each report!

General impression	Author Yes/No/-	Reviewer Yes/No/-
425.Is there a clear formulation of what the PM covers (problem formulation)?	Yes	Yes
426. Are the results reported?	Yes	Yes
427.Is there a recommendation for the project that is useful?	Yes	Yes
428. Is the PM readable without access to task formulation, project instructions, etc. that you received from teachers and supervisors?	Yes	Yes
Technical content		
429.Is the solution method reported, possibly simplifications and assumptions?	-	-
430.Are the results assessed for plausibility?	-	-
431. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	-	-
432. Are equations written as part of the running text, presented in separate lines and numbered?	-	-
433. Can the technical reasoning be followed?	-	-
434. Is there a difference between facts, statements and the author's opinion?	Yes	Yes
Presentation		
435. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	Yes	Yes
436. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor,summary/abstract, table of contents, reference list and page numbering	Yes	Yes
437. Is the report written in third person passive form? Are experiments described in imperfect, e.g. "Trailing tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present tense, e.g. "Calculations show that the natural frequency…"?	Yes	Yes
438. Are figures and tables clear and informative, provided with figure / table text and clear numbering?numbered? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black and white copying?	-	-
439. Are appropriate references made to figure, table and equation numbers in the text?	-	-
440. Are appropriate references made to references in the reference list?	-	-
441. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Yes	Yes
Other		
442. The work has been carried out in collaboration with: _____	-	-
443. The report has been proofread by: _____		-

M104 Production plan hydrofoil



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Version number:	*1.0*
Supervised by:	Jakob and Stefan
Hours worked:	*35*
Reviewed by:	Markus Norberg

Introduction

In order to manufacture hydrofoil mountings and stays, an analysis of methods is made here. A test plan and a production plan are made for use in production. The production plan must be supplemented with better drawings when the motor is delivered.

Problem formulation

According to the decision and report at the project meeting 19/2:

- Hydrofoil angle should be changeable both front and aft to optimize controllability against resistance
- The position of the handles should be changeable to be able to change the possibility of moving the driver's center of gravity
- The location of the strut can be moved backwards to mimic the configuration that has worked best in the experiments but once the floating body is built it cannot be moved.

The mounting plan that exists deals with mountings that are permanently laminated, e.g. between strut and airfoil/motor. In order to be able to change the angles of the hydrofoil, a more flexible solution must be used that allows the angle change.

Suggestions:

The same principle as proposed in the report Hydrofoil and stay ver. 1.5 should be used with some changes. In order to be able to change angles on the front hydrofoil, some kind of joint or adjustable screw solution will be needed. The proposal is to partly build the "sleeve" around the motor so that it goes up a few centimeters around the strut, and partly just have a horseshoe-shaped, aluminum-reinforced flange around the sides and in front of the motor into which you can fasten a loose hydrofoil in the same way as on the experimental craft. This means that you can screw together the top and bottom of the "Easter egg solution" so that it can be assembled apart instead of being laminated together. There is then also the possibility of making an aluminum-reinforced mounting between the "Easter egg" and the strut, which allows those parts to be disassembled as well. Another option plan is to laminate the "Easter egg" together with the strut. The disadvantage then is that it must be possible to open the "Easter egg" in the middle in order to be able to detach the motor without destroying the construction.

One suggestion is that the manufacture of the bulb, also called the Easter egg solution, takes place in two parts; an upper and a lower which are then fastened together. The upper part will serve as the mounting point for the strut. The bulb is assembled together with the aft part, which consists of the shaft, aft hydrofoil and the propeller.

An option that would result in fewer components is to manufacture the entire upper part and the lower part in each piece. In such cases, the plug is shaped according to the total length, i.e. from the leading edge of the bulb to the propeller. Then the two hydrofoils and the propeller are attached to the structure. This variant is somewhat more risky as a small mistake can destroy the entire construction, which causes delays and large costs. The advantages are that there will be fewer parts to assemble, which is preferable in a composite context.

Test plan

A test production will be carried out to investigate the production technology but also to possibly do a destructive test on the construction.
The test points are:

- Lamination around a form
- Production of screw holes and other aluminum reinforced parts
- Fit and stiffness of the flange between “Easter egg” parts

Other things that should be investigated further/again are whether the propeller shaft can handle the torque of the new motor, whether there will be too much twisting or arching of the stay if it is not laminated together, and whether the extra resistance around the shaft due to the stay being filled with water has a bearing on the performance.

Results of test plan

A submarine shaped plug with approximate dimensions as it will be on the real hydrofoil mount was hand laid with carbon fiber and matrix. Image of the construction after lamination is shown in Figure 3. The fiber was laid up with UD fiber in the directions [0 -45 45 90]. In the flange around the front, pieces of aluminum were laminated in to test drill in. On one side it was just aluminum and carbon fiber while on the other side core material was inserted to reduce the angle of the fiber bends and make the construction more streamlined. The stay was made only about 15 cm long to evaluate, above all, torsional stiffness.
Some initial lessons from the lamination were
Some initial lessons from the lamination were to lay up the layers soaked in matrix instead of using staples,
to have a varnished and well waxed plug instead of just aluminum foil to make it release easier and to lay release fabric outside the fiber edges everywhere.
With the test set-up that was done, it will be a very rigid construction. It is easy to get the fit right and the torsional resistance in the stay is considered to be sufficient considering that there is not a lot of torsional load on the stay.
The screw holes became easy to manufacture both with shaped core material and without. Fiber bending radius is not critical without core material, so it is primarily for the sake of streamlining that one would fill in with core material. Aluminum pieces should be laminated in to avoid large local compressive forces directly on the fibers at the screw holes.

Other views and suggestions that have come up during test production:

- There should be something between the motor and the "shell", for example a rubber sheet, which can help transfer loads to the laminate and fill in.
- Templates of segments of the motor should be made to be able to manufacture the plug with as good a fit as possible.

Production plan for hydrofoil mounting and stay

The mounting must be manufactured according to the numbered production plan below. See test plan results above for additional details on lamination and experiences from the test plan. Drawings with exact dimensions and details are produced when the motor is delivered and the dimensions and design of the propeller shaft are determined.

Production plan

1 Before manufacturing laminated parts, the strut should be finished to have a dimensional reference.
2 Aluminum pieces are made - underside of Easter egg, horseshoe flange x2, propeller shaft bearing mount and aft hydrofoil mount.
3 Manufacture of plug for the upper part of the Easter egg and stay according to Figure 2 including waxing.
4 Lamination of the upper part of Easter egg and stay.
5 Adaptation of the plug to the underside or manufacture of the lower plug parallel to the upper plug.
6 Lamination of the lower part of Easter egg and stay.
7 Adaptation and possibly sawing of the stay parts so that they fit together.
8 Drilling holes, adjusting bearing mounting.
9 Possibly extra laminations and streamline adaptation.

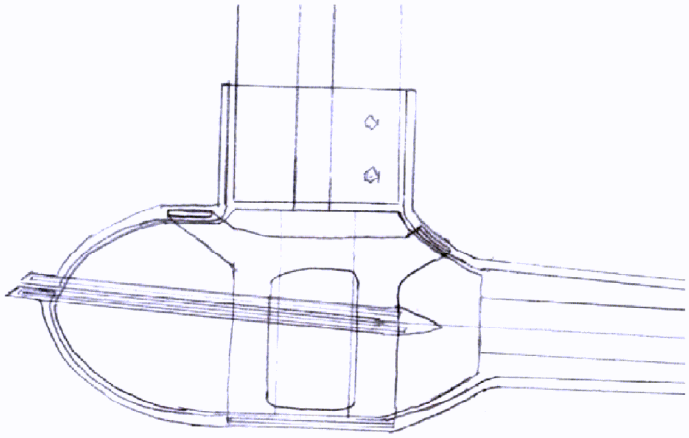


Figure 1. Drawing of "Easter egg solution" in profile. The flange visible in the center should be straight to facilitate manufacturing. The aluminum reinforcement drawn according to the hydrofoil and stay report does not need to be used.

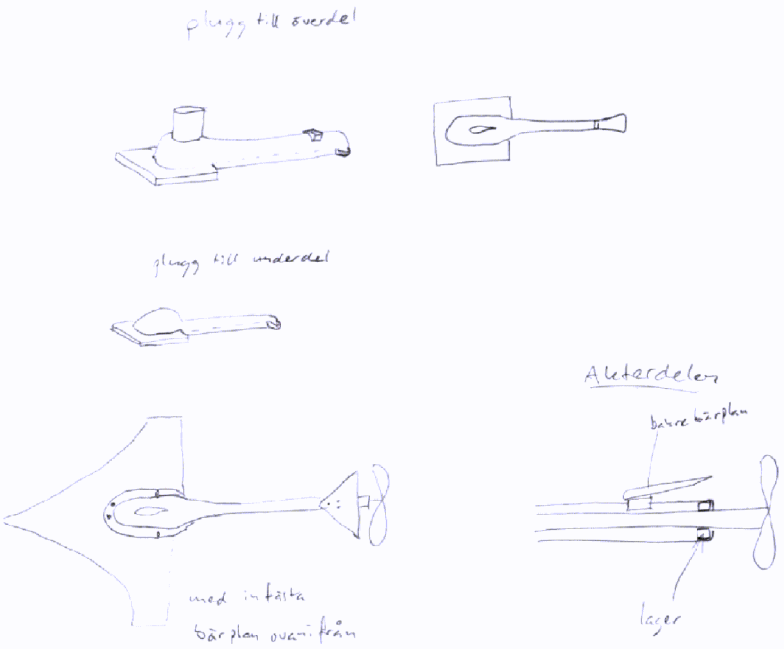


Figure 2. A rough sketch of plugs and mountings for hydrofoil.



Figure 3. Results of test lamination.

Appendix 1 - Checklist for Quality Assurance

The purpose of the list is to function as a structuring support for planning, writing and proofreading reports and as support for self-reflection. The list should be used for feedback from proofreaders. Evaluate each point with yes / no and sometimes with a grade of u, 3,4,5. Note that the completed checklist must be attached to each report!

General impression	Author Yes/No	Reviewer Yes/No
444. Are all elements of the problem addressed?	Yes	
445. Have the purpose and conditions been reported?	Yes	
446. Have relevant conclusions for the benefit of the project been drawn, reported and related to the objective?	Yes	
447. Is the purpose achieved?	Yes	
448. Is the report readable without access to task formulation, project instructions, etc. that you have received from teachers and supervisors?	Yes	
Technical content		
449. Have simplifications and assumptions been clearly stated and justified?	Yes	
450. Has the choice of solution methods been clearly reported and justified?	Yes	
451. Are calculations controlled and reasonably assessed?	Yes	
452. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	Yes	
453. Are equations written as part of the running text, presented in separate lines and numbered?	-	
454. Can the technical reasoning be followed?	Yes	
455. Is there a difference between facts, statements and the author's opinion?	Yes	
456. Is there a realistic verification plan for the work in the report?	-	
457. Is there an acceptable follow-up of the verification plan?	-	
Presentation		
458. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	Yes	
459. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor,	Yes	
460. Is the report written in third person passive form? Are experiments described in imperfect, e.g."Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?	no	
461. Are figures and tables clear and informative, provided with figure / table text and clear numbering? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black and white copying?	Yes	
462. Are appropriate references made to figure, table and equation numbers	Yes	

in the text?		
463. Are appropriate references made to references in the reference list?	-	
464. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Yes	
Other		
465. Has the report been written by you individually?	Yes, us	
466. The work has been carried out in collaboration with: Mattias Kennestad and Fatima Ekekrantz		-
467. The report has been proofread by: Markus Norberg		-
468. I believe that this report as a whole is worth rating (u, 3-5)		
469. The following is a reflection on how I believe that the work with this report and related projects relates to set learning goals (relevance of the work, which goals have been met, etc.):		-

Vinyl ester recipe

			Weight percentage	Hardening time
1	Vinyl ester	Matrix		
2	Cobolt	accelerator	2%	
3	DMA (9826)	accelerator	0.5%	
4	Peroxide 24	hardener	2%	
5	Acetylacetone (9854)	inhibitor	0.05%	33 min
			0.1%	39 min
			0.15%	60 min
			0.2%	120 min

M107 Production plan strut

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Project:	Evolo
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Version number:	*1.1*
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Reviewed by:	Mirjam Fürth

Introduction

This document should facilitate the manufacturer in the process of manufacturing the strut. The document is laid out as a step by step method. The purpose of this document is to ensure the quality of the strut manufacturing process. A complete drawing of the strut can be found in Appendix 2.

Method

Material consumption

Note! The manufacturer must take into account how much waste will be generated in the manufacturing process. This is an approximate material consumption to provide support to the manufacturer.

Core: Divinycell H45

- Volume - 7470 cm^3
- Dimensions – chord = 150 mm, length = 1660 mm, chord thickness = 30 mm

Fiber: carbon fiber

- Carpet with unison fiber direction – 0.83 m2
- Carpet with crossed fiber direction – 1.66 m^2 + carpet for assimilation of profile halves

Matrix: Vinyl ester (recipe appendix 1)

- This field is left unspecified because the uncertainty is too great to determine a matrix input.

Method of manufacture

1.) The core must be sawn to the dimension 150x30x1660 mm and ground to the shape specified in the external appendix which is printed on a 1:1 scale, this appendix can be found in the project folder.
Six layers of fiber must be applied to the core with the fiber direction (main fiber direction 0° is along the length of the support):
   - 2 pcs. layer 0° fiber direction
   - 2 pcs. layer -45° fiber direction
   - 2 pcs. layer 45° fiber direction

   Note! There is no analysis to date that backs up that the fiber directions should be laid according to the aforementioned.
2.) For the manufacture of the vinyl ester matrix, reference is made to Appendix 2.
3.) For instructions on the vacuum injection process refer to TB104 – Fabrication/Materials, Vacuum Injection and Tensile Testing [1].
4.) Cut off the excess laminate at the leading edge of the half profile and sand down the laminate so that there is room to apply new laminate due to the fact that two profile halves must form a whole profile.
5.) Mill out a semi-circle in the core that will go through the entire profile to make room for the rod that sits on the Torqeedos motor bulb (see appendix 1). Note! a milling piece can be mounted on the circular saw (talk to Anders).
6.) Divide the half-profile into two parts with a length of 830 mm.
7.) Assimilation of the two half-profiles

- The excess material at the back edge of the half-profiles provides a good adhesive surface.
- At the forefront, laminate must be put with hand. Carpet with crossed fiber direction Matrix (according to Appendix 1)

8.) Sand and cut away the excess laminate.

References

49. W*olter, N & Ekekrantz,* F: *TB104 - Vakuuminjicering och dragprov.* Marina System, KTH, Stockholm, 2009.

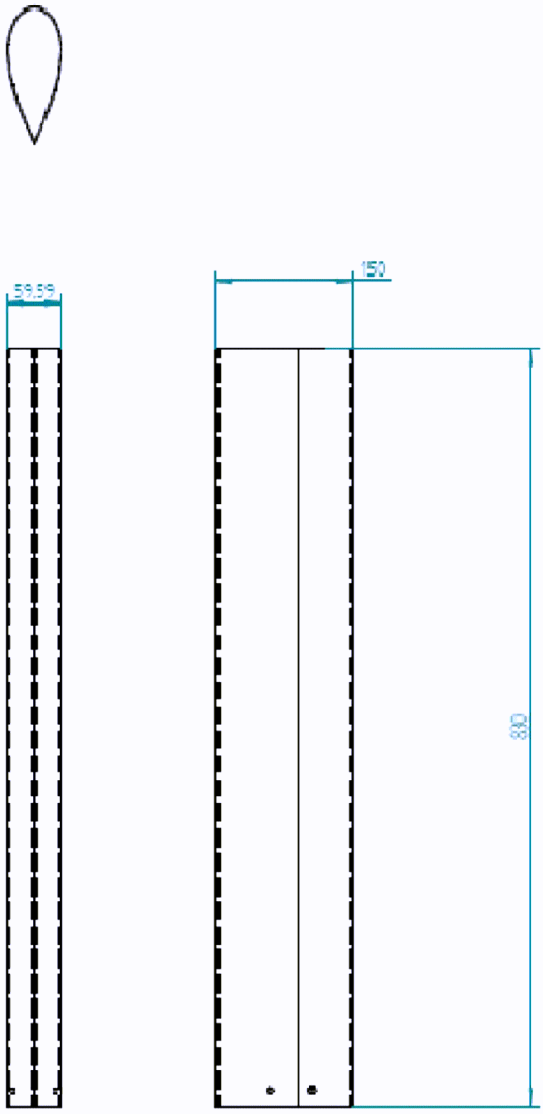
Appendix 1 – Recipe for matrix

Vinyl ester recipe

			Weight percentage	Hardening time
1	Vinyl ester	Matrix		
2	Cobalt	accelerator	2%	
3	DMA (9826)	accelerator	0.5%	
4	Peroxide 24	hardener	2%	
5	Acetylacetone (9854)	inhibitor	0.05%	33 min
			0.1%	39 min
			0.15%	60 min
			0.2%	120 min

Bilaga 2 – Ritning

[mm]



M108. Production plan battery cover



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Date:	*19/03-2009*
Version number:	*1.0*
Reviewed by:	Mirjam Fürth

Introduction

This report provides a tutorial for the manufacture of the battery cover for Evolo and should provide a feasible plan to follow.

Analysis

The hatch that will cover the batteries will take the form of a cover, see figure 1, which can be found in CAD format in the EVOLO CAD folder on the pool computer. Due to its size and shape, it must be built through a hand layup on a plug of cellular foam and then vacuum bagged afterwards to extract excess matrix and achieve a higher fiber fraction in the laminate. It is estimated that no direct calculations need to be performed on this part as it is relatively small and that its geometry will result in a rigid construction and that it can then be built with the same materials and layout as the cover layers on Evlol's floating body. However, it is recommended compared to the cover slip on Evolo to use a safety factor of 2, which then gives a laminate thickness of approx. 2.4mm. This would then be built from 6 layers of carbon fiber in the directions [0.90 0.90 0.90], where the zero direction is in the longitudinal direction of the cover. These layers would then have to be laid on one by one as a hand layup with matrix being added as it goes. In the corners of the plug, joints may need to be added similar to the manufacture of the motor cover to ensure good transitions between the sides and safe power transmission. This means that in the corners slight gaps in the layout can occur and then these must be covered with smaller pieces. In the bottom part of the cover, all fiber layers need to be pulled out approx. 4cm on the aluminum disc used in manufacturing. This as this edge will then be cut to provide an edge for mounting.
The edge is shown in figures 2 and 3. The plug itself is made from two layers of cellular foam that are glued together and then sanded to the desired shape. This will then be attached to an aluminum disc during manufacture and then an edge with putty can be placed in the joint between the disc and the plug to create the rounding shown in figure 2. If the appearance of the battery cover is not desirable, it may need to be painted with a well-balanced color to hide all the shortcomings.

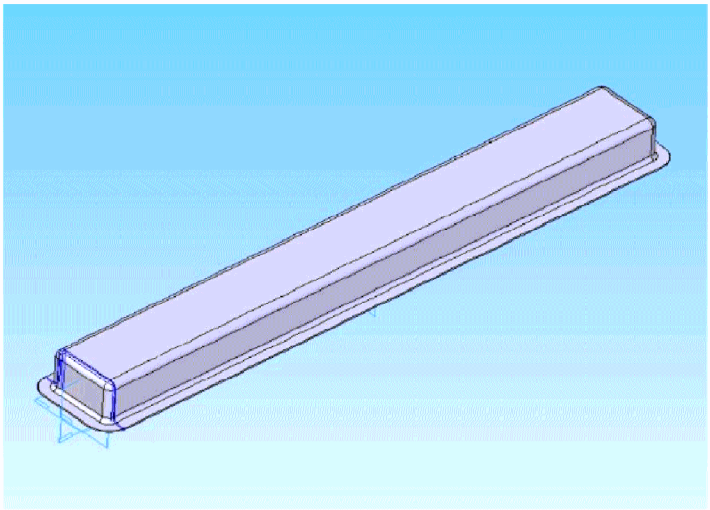


Figure 1. Overview of the cover

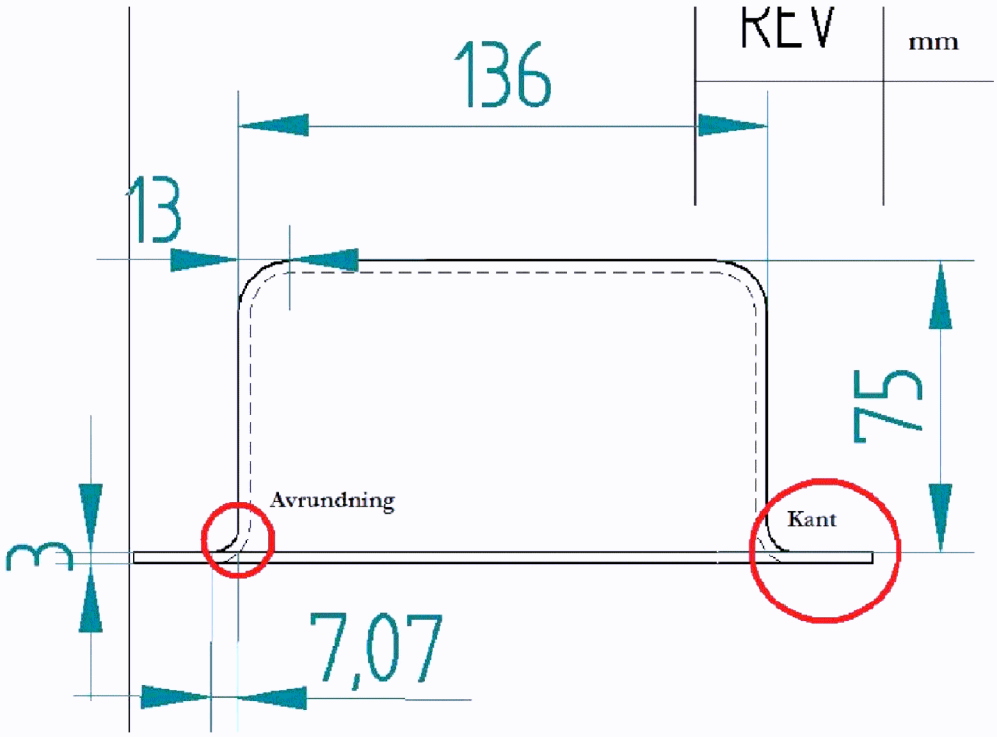


Figure 2. The cover seen from the short side

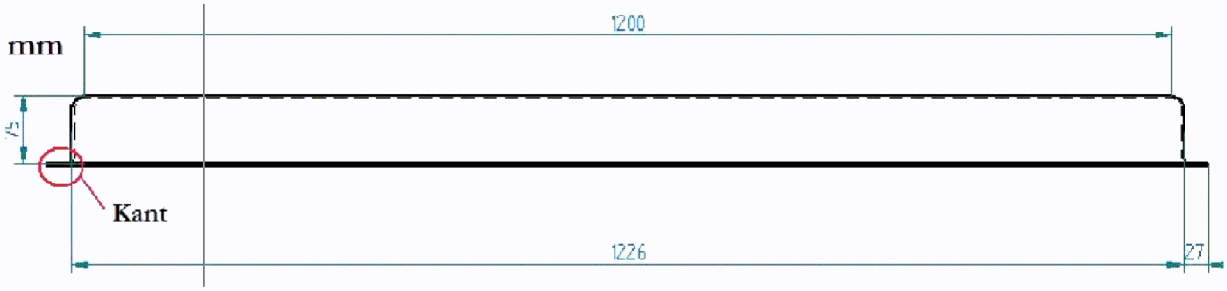


Figure 3. The cover seen from the long side

Step by step

- Cut and glue the parts to the plug
- Sand the plug to the desired shape
- Mount the plug to the aluminum disc (or discs and seal with tacky tape)
- Create the smooth transition between board and plug with putty
- Place a layer of foil on the plug so that the mold releases after hardening
- Cut 6 layers of carbon fiber 0.90 as described above
- Prepare for vacuum bag with tacky tape and other details

- Mix enough matrix for the fibers above, and do a little extra as it is a hand layup. Vinyl ester recipes and setting times can be found in the M105 hardening time matrix. 60 minute hardening time is recommended
- Make hand layup of the cover
- Vacuum bag the plug

CONFIDENTIAL WD086627

Test injection of floating body



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FATIMA

EKEKRANTZ

MARKUS NORBERG

JOACIM WESTLUND

Course: Lightweight design
Project: Evolo
Date: *3/3-2009*
Version number:
Supervised by:
Reviewed by:

Introduction
The purpose of this experiment is to carry out a full-scale vacuum injection to primarily test the injection time and how it differs between the top and bottom of the floating body. Other tests that are carried out are tests of the insertion of a metal plate into the core material, the wrapping during injection, surface treatment and matrix access.

Performance
A two-decimeter long cross-section of the floating body is produced by Divinycell, which should correspond to the part of the floating body with the greatest thickness. A recess in the core material is made and a metal plate is inserted. The core material is covered with carbon fiber with the lay-up sequence 0/45/-45. The cross-section is prepared for the vacuum injection according to previous reports, two layers of distribution tissue are used on the underside and six layers on the top. This is to get the same injection time on the bottom and top side. Matrix is mixed according to the vinyl ester recipe (available at Bilda), the calculated amount is twice the percentage by weight of the percentage of fiber to be on the safe side.

Results
The injection time is approximately 40 minutes on both the lower and upper side. "Race tracking" occurred at the bottom of the sides of the core which increased the matrix consumption but otherwise did not affect the result. To avoid this, it is recommended that a lot of cover plastic is used so that the core material is well enclosed when vacuum pressure is applied. Furthermore, it is also recommended that the pressure be lowered very slowly in connection with the throttling of the matrix supply to avoid air bubbles in the composite.

M110 – M110 – Mounting strut / hydrofoil

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Project: Evolo
Date: *3/3-2009*
Version number:
Supervised by:
Reviewed by:

The purpose of this report is to determine what the mounting between the strut and the hydrofoil should look like. *Fig. 1* shows what the mounting should look like. *Fig. 2,3,4,5* shows step by step how the production should be done.

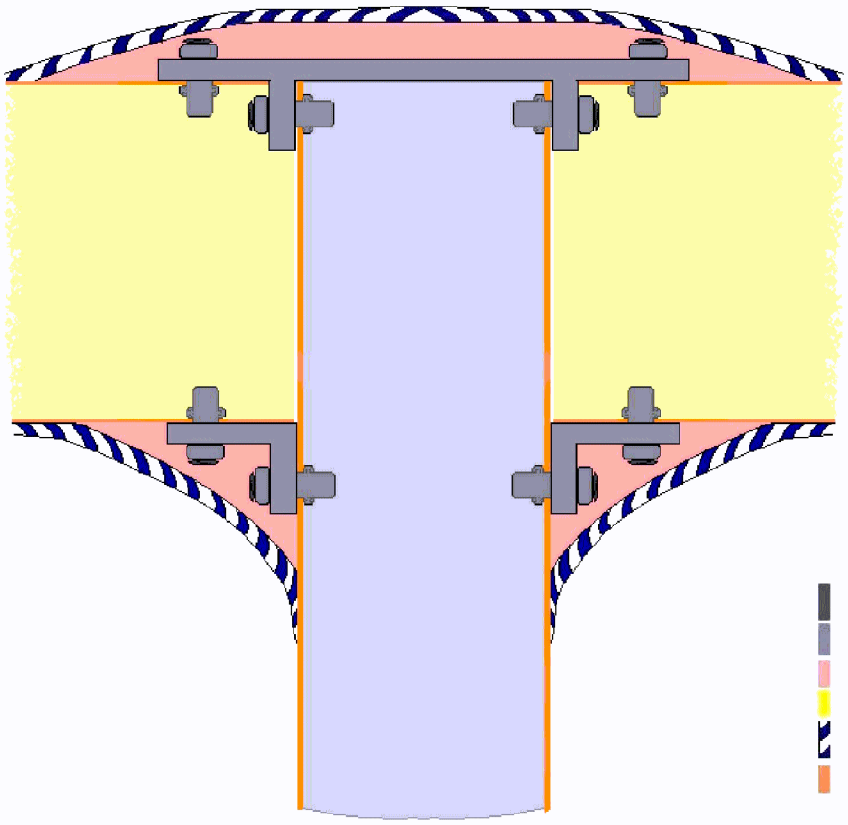


Figure 1. Final mounting

Critical parts of manufacturing are the metal flanges that are to be shaped to fit the elliptical shape of the strut. Between the composite cover layer and the metal flanges, a filler should be used so that the fibers will lie better against the metal flanges. This filler must be sufficiently rigid to carry the resulting loads. Depending on the core material to be used, wood or Divinycell with a high shear modulus, different types of screws should be used. If wood is used, wood screws can be used. If Divinycell is used, a tensile test must be performed to see if wood screws are to be used, which is advantageous. If Divinycell does not fit together with wood screws, a type of rivet must be used that attaches to the cover layer. These can be ordered from www.colly.se. However, both solutions are feasible. The recommendation is to use Divinycell H200 and rivets to save time and not have to perform tensile tests.

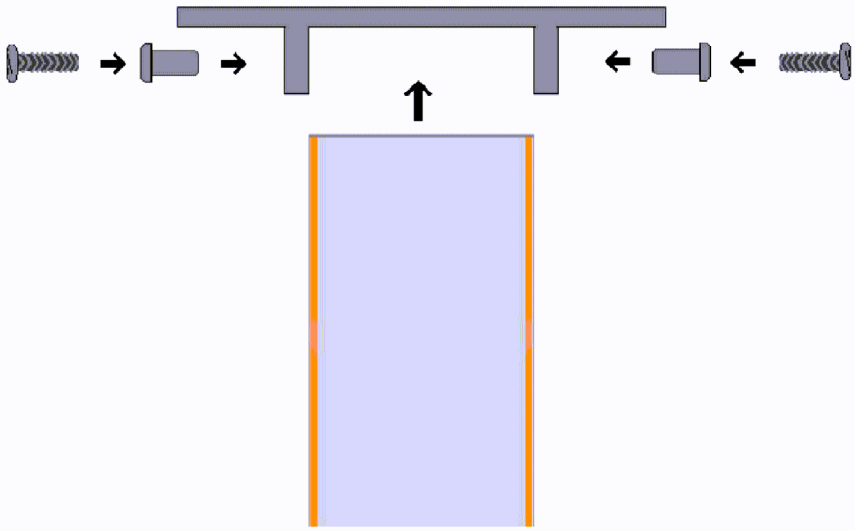


Figure 2. mounting step 1



Figure 3. Mounting step 2

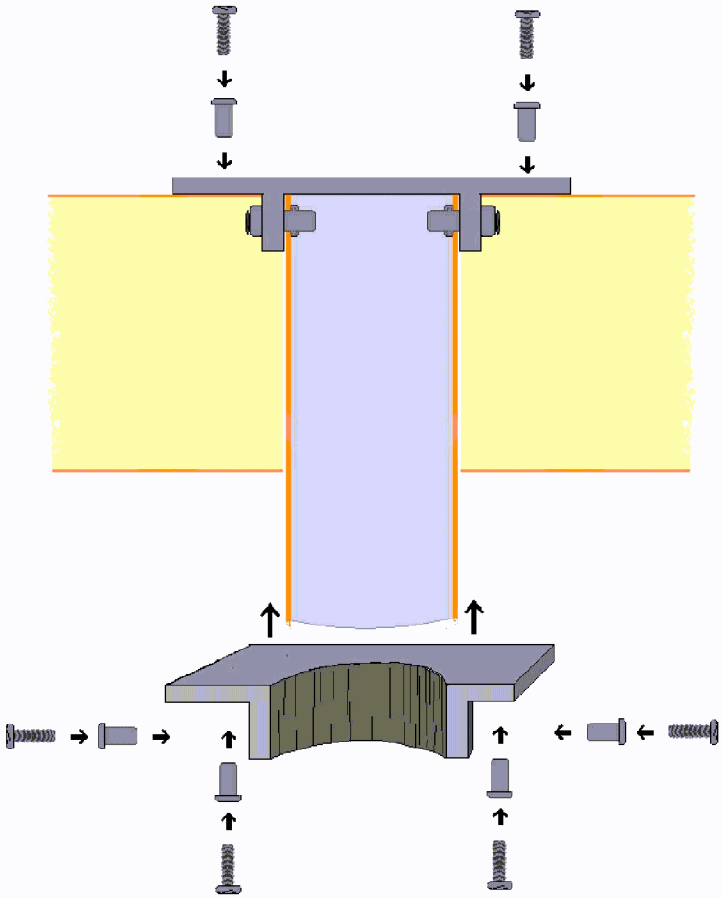


Figure 4. Mounting step 3

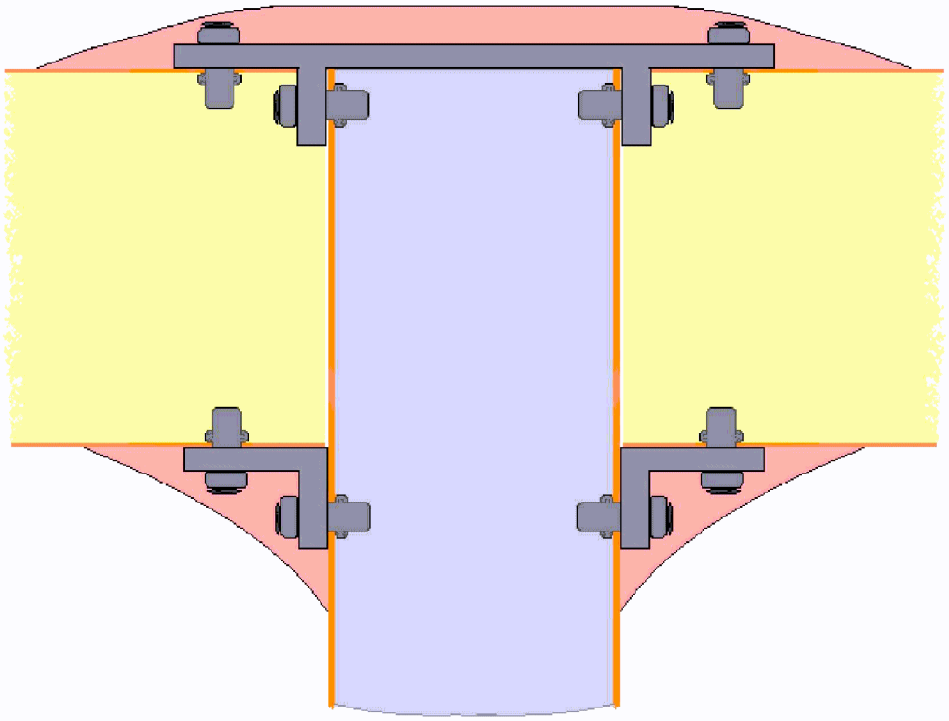


Figure 5. Mounting step 4

PM
E104 -Financial report



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Course:	Marine design
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Version number:	*1*
Supervised by:	
Hours worked:	On the report 4 hours, the financial work in total maybe 30 hours
Reviewed by:	Mirjam Fürth

Introduction

This report summarizes the project's finances up to 24/3-2009. At the time of writing, the final cost picture is not clear as not all invoices have been received. In cases where these have not yet been booked, this is indicated with the forecasted cost.

Basics

The project has made full use of KTH's finance department. The Marine Design course has an account linked to it which is 21012. The administration of the account is handled on craft and flight by Ann-Britt Hansen. The cooperation with Ann-Britt has worked very well. We have managed the finances with the principle that larger incomes and expenses are invoiced. This has worked very well. Admittedly, there will be a bit more bureaucracy, but the advantage is that the project does not have to pay VAT. Some companies have invoice routines already worked out by KTH so that even small expenses can be easily invoiced. For other expenses from, for example, construction markets, retailers, mileage allowances, etc., I have compiled receipts and sent documents to Ann-Britt who then paid to my account from where I paid out to those who made the expenses. This has also worked very well and the advantage is that they don't have to add every single person to KTH's salary register, even if it meant a little extra work for me.

Budget

During the autumn, a budget was drawn up by Anders Lundell [1]. This estimated the project's need for funds to cover all costs at SEK 94,000. This included costs for all materials and that we would participate in the boat fair. However, the boat fair was chosen at an early stage, which reduced the budget by about SEK 30,000. Thus, the project's budgeted need for funds was 64,000, of which the larger items were a motor for 25,000 SEK and batteries for 20,000 SEK.

Income and sponsors

The project has received SEK 20,000 from Marina System. During the autumn, there was intensive work on looking for sponsors. This work is described in more detail in the report E101 - Report sponsors [2]. This report describes in more detail the process of the sponsorship work and which companies were contacted. In general, the interest was lukewarm and during the autumn we received a sponsor from the KBT Group (SEK 5000) thanks largely to the fact that one of the project participants had a personal contact there. At the beginning of the spring term, a retake was made and we finally got 2 more sponsors. The company Seaware contributed SEK 5,000 and Solna Korv with SEK 2,000. In parallel with this, we signed up for the competition KTH på insidan (KTH on the inside) where 3 projects would be selected and noticed in a campaign to inform and attract young people to technical education. We managed to win one of the places and thus received SEK 75,000 for the project. In table 1, a summary of the income is shown.

Table 1 The project's income

Listing	Income
KTH Marina System	SEK 20 000
KBT Group	SEK 5,000
Seaware	SEK 5,000

Solna korv	SEK 2,000
KTH on the inside	SEK 75,000
Total	SEK 107,000

In addition to this, Reichold has sponsored us with 40 kg of matrix for the plasticizing (approx. SEK 2,400) and Diab with Divinycell in the form of core material (approx. SEK 8,000) for the various parts. Another part that can be considered sponsorship is the material we used in the lab. It is difficult to estimate the value of this as there are several of us who use the resources and it is not clear what each thing costs. According to Anders Beckman, director of the lab, a total of just over SEK 30,000 worth of material was used during the spring. This is then distributed among all the people/projects that use the lab, but still gives an indication that we have used material for the plasticization for a couple of thousand. A rough estimate is that the value of Evolo's part is SEK 5,000. In total, the non-monetary sponsorship is thus worth approx. SEK 15,000. In addition to this, we had to take leftover carbon fiber of lower quality completely free of charge.

Expenses

Table 2 shows a compilation of the project's actual costs, i.e. costs as generated expenses. The costs are reported excluding VAT because we are exempt from it.

Table 2 Expenses

Listing	Cost
Battery purchase excluding customs duty	SEK 13,379
Motor purchase, estimated cost, not yet paid final amount depends on the euro exchange rate	SEK 20,250
Payment 1 small payment	SEK 1,182
Payment 2 small expenses and mileage reimbursement	SEK 2,231
Estimation of further additional costs in the project before Evolo floats	SEK 4,000
Total	SEK 41,042

The expensive parts of the project are the motor and batteries. Both were cheaper than we initially budgeted for. The items small expenses include costs for website and web hosting, purchase of screws, glue, plywood, putty, etc. The last item of SEK 4,000 is a highly calculated estimate of not yet incurred costs directly linked to the construction of Evolo. This includes any customs duty for the battery purchase, which at the time of writing is not clear what it will be.

Summarization

The project's finances include incomes and material sponsorship of approx. SEK 122,000. If the income is subtracted from the expenses, approximately SEK 67,000 remains in profit for the project. The project has jointly made the decision to use excess funds for a joint end.
Any additional surplus is funded for next year's students. Compared to the budget, the actual cost of Evolo turned out to be cheaper than budgeted. However, if you take into account that we were sponsored with materials and received free carbon fiber, we end up with a cost of approx. SEK 55,000 + and considering the difficulties in estimating the value of sponsorship, our budget was relatively realistic.

Conclusion/experiences

Looking for sponsors is not always so easy. Above all, we had problems with the recession hitting and causing the companies to turn a blind eye. It was a little easier with the sponsorship of material and getting lower prices. In general, the advice is to start well in advance, especially with those from whom you are seeking money. For those who might consider contributing material, it is probably good to wait until you know exactly what you need.

Managing the finances is made easier by the fact that the project had its own account. As it is now, the project has a joint account with the course itself. This combined with a fairly messy financial system makes it difficult to keep track of because our expenses are mixed with Jakob's cake party, book purchases, etc.

References

50. Lundell, Anders: Evolo - Budget, KTH, unpublished
51. Lundell, Anders & Ekekranz Fatima, E101 - Rapport sponsorer, KTH, unpublished

Appendix 57 Xf2 Experiment 1, planning

Background for experiment 1



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Background for experiment

Introduction

This draft should be seen as a basis for the construction of a test rig, with the aim of investigating certain maneuvering characteristics of a motor-driven and hydrofoil-borne craft (figure 1). This test rig must be built, tested and evaluated during the period from October 2 to October 22 inclusive. The results should be able to be used to develop the conceptual design to be delivered on October 29. The experiments are divided into phases, 1 and 2, where the initial goal is to get the craft up on the hydrofoil and get a subjective idea of how it is handled during take-off and progress, as well as estimate the hydrofoil size. Phase 1 must be completed on October 22. Phase 2 is not fixed in time.

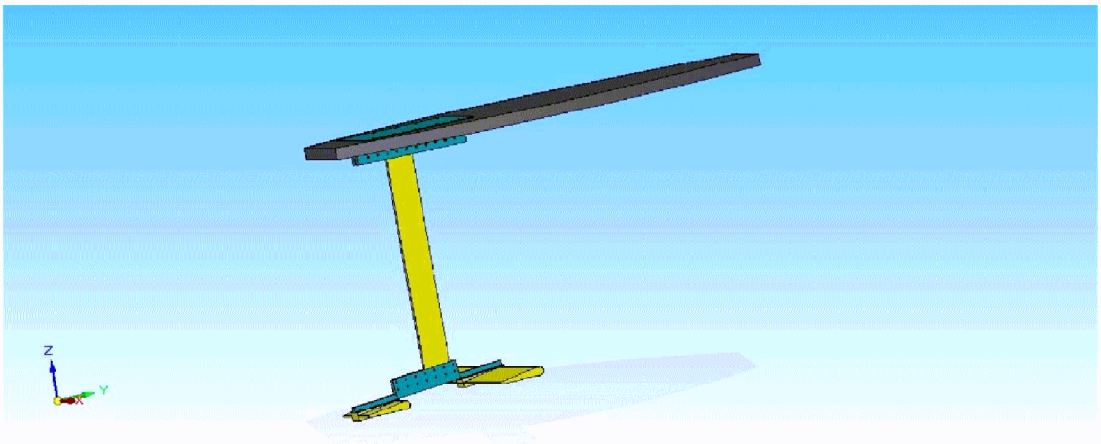


Figure 40. Sketch of craft.

Purpose

The purpose of the experiment is to investigate the craft's characteristics with regard to the following:

- Center of gravity and displacement of the center of gravity when starting and traveling with the craft
  - At take-off, a very large moment will act to rotate the craft backwards, this must be counteracted somehow. The experiment can show how this can be achieved, either by means of shifting the center of gravity, placing the strut relative to the floating body, or a combination of these. (PHASE 1)
- Necessary thrust to propel the craft on the hydrofoil
  - Do a stress test at a range of speeds to get a rough estimate of propulsion resistance. (PHASE 1)
- Estimate resistance for test rig at various configurations
  - Investigate whether there is a large difference in resistance for different hydrofoil configurations and strut placement. (PHASE 2)
- Investigate how the craft is perceived to be handled by a person in the water
  - A more subjective survey that can be related to ergonomics and ease of use at a later stage. (PHASE 2)
- Estimate how stable the craft is when moving forward and starting
  - How "difficult" is the craft to fly and how does the choice of wing profiles affect this parameter.
- Investigate positioning of the user.
  - How can the user be positioned, standing, kneeling, etc. What is easiest or hardest. (PHASE 2)
- The influence of the profile's plan form, aspect ratio and location. (PHASE 1 and 2)

Timetable phase 1

The following table is an estimate of the required construction time, all estimates are well scaled to provide a time buffer for construction and testing. The available time is divided among 6 people who must simultaneously prepare a test plan and protocol.

	Time required [h]
Steel work for mountings	10
Delta wing	9
Traditional wing	9
Control wing (trim)	9
Strut	5
Putting together	18
Total	60
Available	60

Construction takes place during free time on Tuesday 7/10 and Thursday 9/10 and assembly on Tuesday 14/10. The experiment is carried out on Thursday 16/10, with a buffer on Saturday 18/10.

Requirements for the model

To build the model in the specified time period, simplicity and robustness are a requirement. The experiment is not intended to produce accurate data for stress or center of gravity, but rather an attempt to get a picture of how component and center of gravity placement affects craft maneuverability and performance. It is therefore of the utmost importance that its configuration can be changed quickly and easily. The points that, according to the investigation group, may need to be adjusted are the following:

- The pull, that is, where the rope that pulls the craft is attached vertically
- Length of the strut
- Placement of the strut relative to the floating body
- Size of hydrofoil
- Placement of users
- Placement of the strut relative to wing profiles

Test methods phase 1

- Tensile test
  - In hydrofoil mode
  - In displacement/start mode
  - This should be tested with several different configurations
- Evaluate center of gravity location
  - Markings on the floating body
  - Both at takeoff and hydrofoil speed
  - Tried with several different configurations
- How is the craft perceived
  - Create evaluation form for handling and stability
- Documentation
  - Photographing and filming the experiment

Equipment

- Dynamometer
  - A simple dynamometer must be constructed to estimate the propulsion resistance, for example using a spring or shockcord. (Micke)

- GPS
  - Required to measure speed through the water and relate this to resistance and when the craft is lifted onto the hydrofoil. (Mickey fixes it)
- Tow lines
  - Suitable tow lines to perform the experiment. (Micke)
- Test rig
  - The test rig shall be built during the period 7/10 – 16/10.
- Dry suit, gloves, etc. (Micke)
- Tugboat (Jocke or Jakob)
- Test protocol (Micke)
- Scale
- Camera

Material

The test rig must be able to be built in a very short period of time and it is of the utmost importance that as simple materials as possible are used, i.e. easily processed.

- 18 mm plywood for wing profiles and strut.
  - - Easily processed and cheap material
- Steel for structure to carry the hydrofoils and strut
- Floating body of foam-filled polyester plastic, (old surfboard)
- Various mounting material
- Paint to protect plywood

Construction

An investigation of the hydrofoil construction by the analysis group and the experimental group shows that the following size of hydrofoil provides the desired lifting force. The groups estimate that 1100 – 1200 N of lifting force is required to get the craft hydrofoil borne Depending on the speed employed, here 6 – 8 knots, to achieve this carrying capacity the size of the hydrofoil varies, based on this data 2 profiles must be built and evaluated.

	Delta wing	Traditional wing	
Chord	570 - 730	160	[mm]
Width	420 - 530	1000	[mm]

Other components are designed by common sense and engineering judgment, for drawings see Bilda under experiment - drawings.

Safety

The safety of the user is of the utmost importance during testing. The craft must be able to be released immediately should something happen. This can be done by never attaching the towline to the towboat. Handles or other types of fittings must be provided on the craft that enable the user to hold on. Life jackets and dry suits are mandatory.

Evaluation

The data in the form of subjective experiences and measured data must be delivered to the analysis group for evaluation. This must take place by October 22 at the latest. Test protocols must be completed and saved on Bilda. Xf2- Test protocol is on Bilda under experiment.

Economy

The cost of the experiment is reported separately in the Xf2 budget at Bilda.

Experiment 1

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Course:	Marine design
Project:	Evolo
Date:	*24/10-2008*
Version number:	*1.0*
Supervised by:	Jakob Kuttenkeuler
Hours worked:	-
Reviewed by:	Erik Jerilgård, Fredrik Bender, Daniel Carlsson

Introduction

This report summarizes the results that experiment 1 gave on October 18 in Saltsjöbaden. The purpose was to investigate certain maneuvering characteristics of an hydrofoil-borne surfboard, Evolo, and to investigate whether the construction was possible. The experiment was successful in the sense that the craft took off at the calculated design speed, 6 knots, and the experimental group managed to confirm some data regarding the type of hydrofoil that is suitable to use. A degree of difficulty for the user could be identified, through three different test pilots, all of whom had different experiences in water sports.

Summary

The main points that the experimental group and especially the test pilots could agree on, regarding the craft itself, were that:

- Evolo was less sensitive to disturbances and easier to handle with a delta wing.
- steering in motorcycle position was experienced easiest.
- the stern was most difficult to handle in pitch direction, however better with a negative angle on the aft wing, however it was felt that this gave greater propulsion resistance. The driver was positioned very far forward in relation to the strut.
- It was very important to be able to quickly shift the driver's center of gravity.
- It was important to have fixed points to hold on to in order to be able to turn the craft around the vertical axis.
- major problems were experienced in ventilation of the wings, the pilot lost control completely.
- a floating body that can handle "dipping" well is important, both for waves and to give the driver a smoother ride with less disturbing splashes in the eyes.
- steps and suitable support for the knees were desired by all drivers, these should be adaptable for different lengths of pilot.
- a longer floating body than the one used in the experiment to be able to place the center of gravity far from the center of lift.
- safety plays a decisive role, how should it be handled? The test pilots were both run over by the craft and fell on the wings.
- an estimated 30 – 50 kg of traction was required.
- Rolling stability would perhaps be better with angled ends of the hydrofoils.

Task formulation

The experiment will investigate the maneuvering characteristics, balance and to some extent resistance, of an hydrofoil-borne craft. This craft, Evolo, is built according to the experimental plan found on image [1]. The test was carried out using a towing boat to simulate propulsion. The result will provide input to the analysis and design groups for further development of Evolo.

Performance

The test was carried out on 18 October in Saltsjöbaden, during a full day the model was driven behind a towing boat with three different test pilots. During this test day, a number of different configurations were tried on the Evolo and trials were carried out to evaluate the impact of these configurations on maneuverability and resistance.

The test was performed according to the safety guidelines documented in the experimental plan [1], which proved to be very important. The loads on the towline become very large when the driver loses control of the craft, and the ability to quickly relieve the towline was extremely important. A learning period for each driver was allowed to provide better test results.

Test result

The following observations and subjective experiences could be documented during the experiments.

Attempt 1

Lifting wing: Delta 10°
Stability wing: Delta 0°
Driver: Erik Jerilgård

The attempt is successful. The prototype rises at a very low speed, about 6 knots, however, it is not possible to apply the traction force in the lower mounting point on the prototype as this overturns the craft when it starts to rise out of the water. This was solved by having two rope ends from the boat to the prototype and that the test pilot can hold this with his hands. However, the prototype feels unstable and when it starts to swing and roll, it becomes next to impossible to right itself up, causing it to capsize. This must be solved in attempt two with the help of a smaller angle of attack. However, the first attempt gives a good feeling for how you should sit/lie down to keep your balance.

Attempt 2

Lifting wing Delta 5°
Stability wing Delta 0°
Driver: Micke Razola

Attempt successful. The prototype lifted off at 5-7 knots. Lower mounting point and longer line meant less jerky movement. The driver considers it to be stable in rolling as he sits in a motorcycle position and compensates, among other things, by adding small, fast turning moments to the craft. Stability in the pitch direction is not good due to the fact that correction of the center of gravity cannot be carried out quickly enough. Pulling from the rope means that the driver has to correct his center of gravity very quickly. The driver thinks it would be easier with proper handles. The strut is moved aft to give a larger lever to the driver, this gives better control in the pitch direction and enables a higher acceleration.

In an instant there is a big change in lift and the prototype takes off very quickly. The bow rises very quickly and makes it impossible to move the center of gravity forward. Therefore, in the next trials, a positive angle of attack is set on the rear fin so that both the lifting and stabilizing wing provide a uprighting torque. The hope is that this can be balanced out by the driver's center of gravity so that it provides an equilibrium.

Attempt 3

Lifting wing Delta +5°
Stability wing Delta +5°
Driver: Micke Razola

Very long rope, which makes it less jerky. The driver does not notice a difference with the changed angle, but comes up properly (motorcycle position) and can control the craft to some degree in flying position for a short time: one to two involuntary, but compensated, turns. Faster acceleration is tested and does not work because the craft rises very quickly and the driver does not have time to compensate the center of gravity.

Attempt 4

Lifting wing Delta +5°
Stability wing Delta -10°
Driver: Micke Razola

Better control in pitch direction, with a negative angle on the aft wing. The craft feels controllable at the designed lifting speed of 6-7 knots, but at higher speeds, the lifting force from the wing profile becomes very large even at small angles of attack. The better pitch direction stability would perhaps be even better if the lever between the small and the large wing was larger. The whole craft felt slower on this run, the group at the boat also felt that it was heavier to pull. The craft takes off completely at 7.5 to 8 knots. The driving position that is most easily experienced is the motorcycle position, as you can move the craft under you in all directions and thus control direction and height.

Attempt 5

Lifting wing Delta 0°
Stability wing Delta -10°
Driver: Erik Jerilgård

Difficult to get the craft to take off.

Attempt 6

Lifting wing Delta 0°
Stability wing straight -10°
Driver: Mattias Schönning

New, heavier driver and new stability wing. The driver gets into flying mode after a few tries, but heavy resistance and a lot of motor power. Comes up in flying mode at slightly higher speed, about 7 knots. The driver finds it quite easy to get up. Flying and controlling in pitch direction the longest so far, estimated at about 5 seconds.

Attempt 7

Lifting wing Straight 0°
Stability wing straight -10°
Driver: Mattias Schönning

New main wing. The craft has less resistance in the water. Less stable in pitch direction. Coming up at the lowest at 7.6 and the highest at 8.9 knots, and it was more stable in the 8-9 knots range. The craft "jumps" easily and quickly. No perceived difference in roll direction.

Conclusion

Furthermore, some reflections were made on the experiment and the methods, models and improvements that could be made. An important observation was that the drag behind a large motorboat gives a very jerky, i.e. difficult to handle, ride. This was improved with a longer pull rope, but the experimental group felt that this should be made even more damped to reflect the power of an motor on the craft. A better movement model should be developed to give a better idea of how the configuration affects the stability, especially in the pitch direction.

A floating body that provides better hydrodynamic properties should be developed and possibly tested in test number two. Partly to minimize resistance in displacing mode, but also to facilitate handling on the hydrofoil when the craft dips into the water.

Other safety aspects were also brought up, when the test pilots both fell on the wings of the craft and were run over. These observations are important to communicate to other project groups and work to minimize these risks is recommended by the experimental group.

The experience from the construction also brought up weak links in the structure, among other things the torsional stiffness of the strut was a problem that arose. These experiences are important to bring into the analysis phase, to facilitate the work.

Documentation of the trials can be found on youtube [2], after a search on Evolo.

References

1. Xf2 - Experimentplan, http://www.bilda.kth.se
2. Xf3 - Experimentvideos, http://www.youtube.com

X4 - Experiment Background



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Version number:	*1.0*
Supervised by:	-
Hours worked:	*4*
Reviewed by:	-

Introduction

This draft should be seen as a basis for the construction of a test rig, with the aim of investigating certain maneuvering characteristics and resistance for an motor-driven and hydrofoil-borne craft (figure 1). This test rig must be built, tested and evaluated during the period from November 10 to November 12. The experiment should be seen as a follow-up to the data experiment 1 generated and which the analysis group then used to construct test rig number two [1], [2].

Important lessons learned from the previous experiment in terms of test methods must be incorporated into this evaluation in order to generate as much valuable and accurate data as possible.

Purpose

The purpose of the experiment is to investigate the craft's characteristics with regard to the following:

- Necessary thrust to propel the craft on the hydrofoil
  - Do a tensile test at a range of speeds to get a rough estimate of propulsion resistance.
- Investigate how the craft is perceived to be handled by a person in the water
  - A more subjective survey that can be related to ergonomics and ease of use at a later stage.
- Estimate how stable the craft is when moving forward and starting
- Investigate positioning of the user.
  - How can the user be positioned, standing, kneeling, etc. What is easiest or hardest.
- The influence of the profile's plan form, aspect ratio and location.

Schedule

The following table is an estimate of the required construction time, all estimates are well scaled to provide a time buffer for construction and testing. The available time is divided among 6 people who must simultaneously prepare a test plan and protocol.

The construction takes place during free time on Tuesday 10/11 and Thursday 12/11. The experiment is carried out on Tuesday 18/11.

Requirements for the model

In this experiment, the demands on the test rig increase significantly. The first experiment was intended to investigate the feasibility of the project and to some extent the maneuverability of the Evolo, this follow-up experiment will produce resistance and maneuverability data for a test rig that approaches the concept design.

Test methods

- Tensile test
  - In hydrofoil mode
  - In displacement/start mode
- Evaluate center of gravity location
  - Markings on the floating body
  - Both at takeoff and hydrofoil speed
- How is the craft perceived
- Documentation
  - Photographing and filming the experiment

Equipment

- Dynamometer
  - A dynamometer that provides the desired accuracy at 20 – 60 kg traction force.
- GPS